OL. XXVII. — No. 2. FEBRUARY 1950.

Monthly Bulletin of the International Railway Congress Association

(English Edition)

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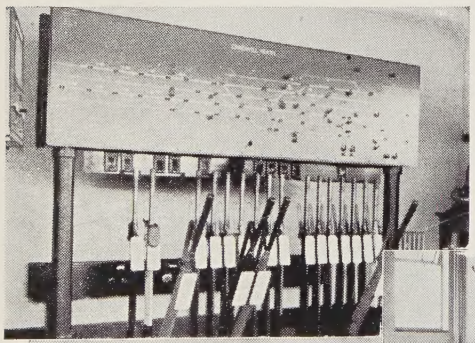

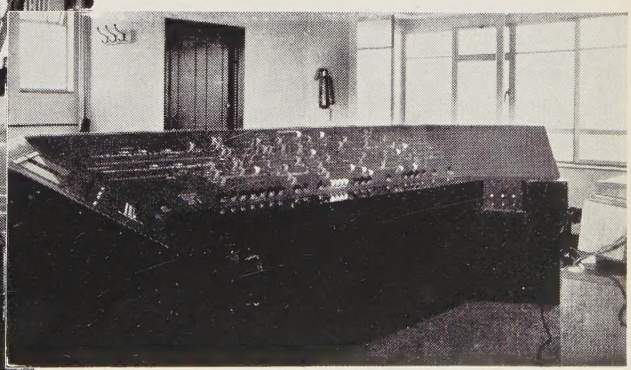

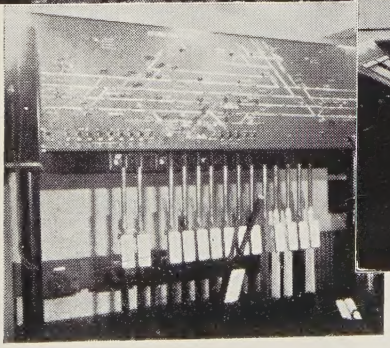

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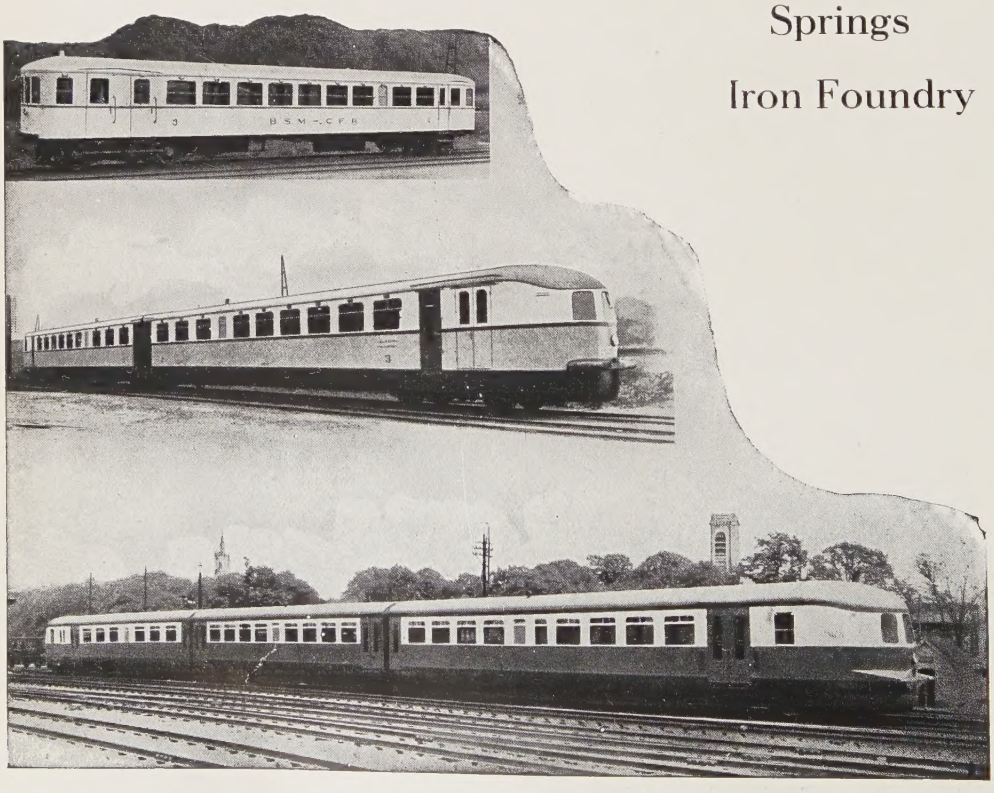

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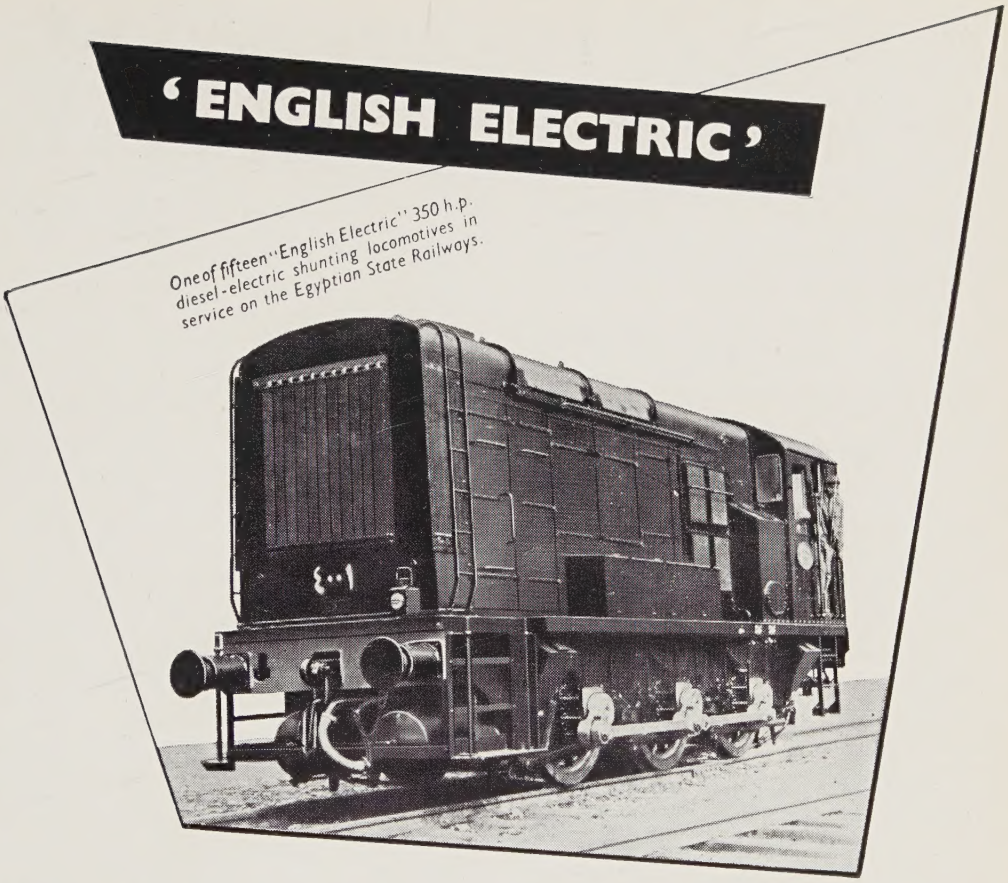

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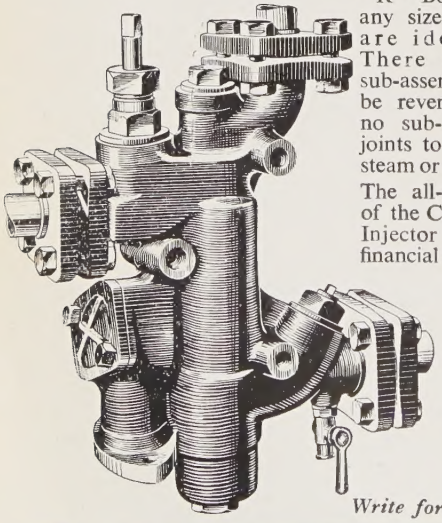

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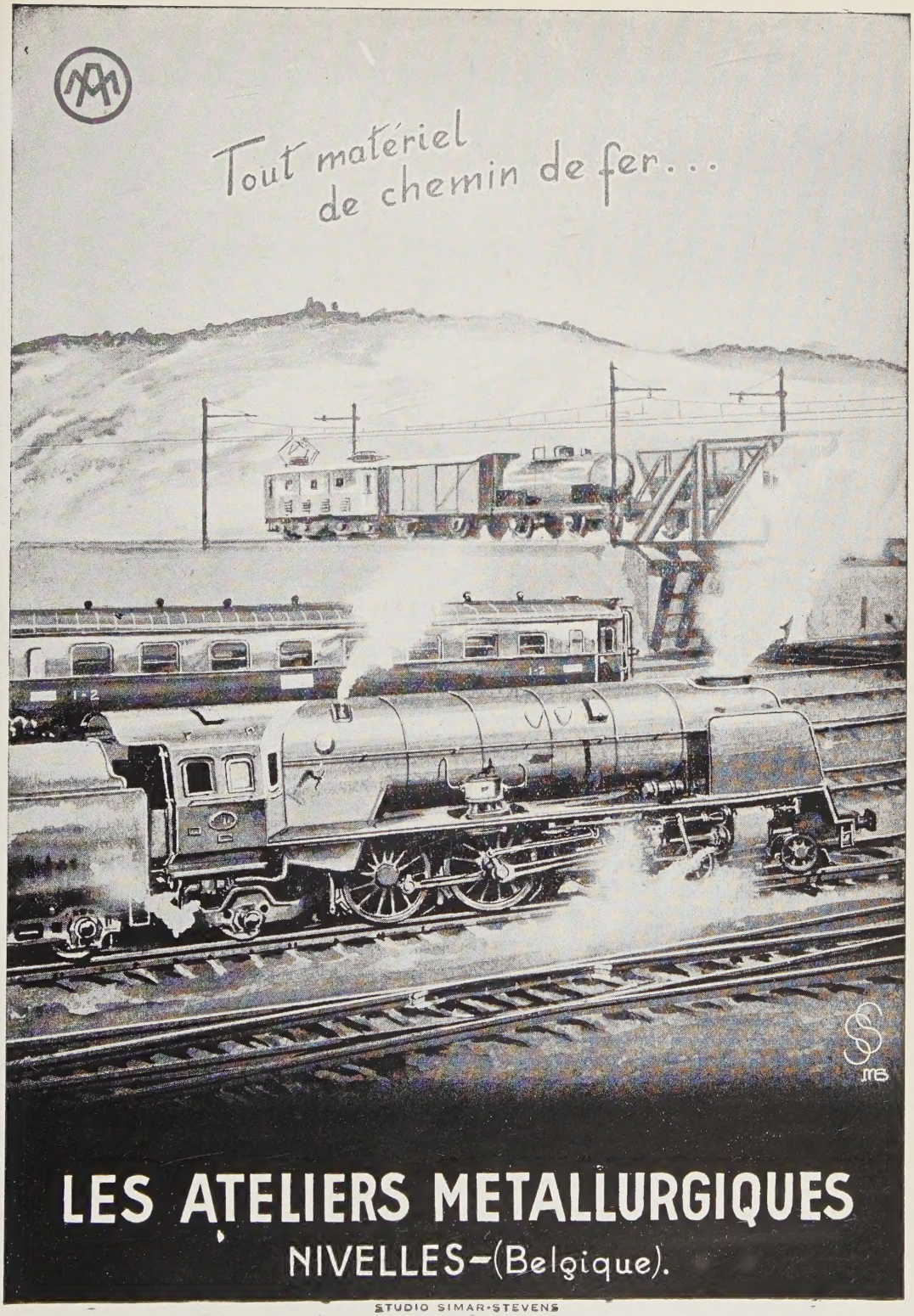
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OF THE

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Vol. XXVII. — No. 2. February 1950.

BULLETIN
OF THE
INTERNATIONAL RAILWAY CONGRESS
ASSOCIATION
(ENGLISH EDITION)

[625 .251]

Research into a method of calculating the stopping distance in the case of goods trains retarded by continuous compressed air brakes, with progressive charging of the brake cylinders,

by Edgar Hennig,

Ingénieur Civil des Mines, Ingénieur principal honoraire S. N. C. B.

SECOND PART (*)

Case wherein a rather long train moves during a brake application over a section of line of varying gradient.

CHAPTER I.

PRELIMINARY REMARKS.

If during the braking of a fairly long train, it moves over a part of the line the gradient of which is *not constant* the term iP in the differential equation of the movement of the train represents evidently a *variable* whereas the same term has a constant value if the train passes over a part of the line the gradient of which is constant.

It will be realised that the value of this variable depends, at each instant, on the relative situation of each of the various elements of the train relatively to the diverse elements composing the profile of the section of the line under consideration.

Let us take a simple case (Fig. 1).

Let us consider for example a goods train of a total weight of P tons formed of a locomotive weighing P_1 tons and a rake of wagons weighing P′ tons.

Let the length of the locomotive be l_1 metres and that of the rake L′ metres, the total length of the train = L metres = l_1 metres + L′ metres.

Let $p_1 = \frac{P_1}{l_1}$ tons the weight of the locomotive per metre and $p' = \frac{P'}{L'}$ tons, the weight of the rake per metre.

Let us admit that during braking the train runs over a part of the line with an irregular gradient made up of an element with a gradient of i_1 millimetres

(*) See First Part in the *Congress Bulletin*, for March (p. 139) and April (p. 201) 1948.

per metre, followed by an element of i_2 millimetres per metre.

Let us suppose that when the brake was applied the whole train was on the element with a gradient of i_1 and that at this moment a distance of L_0 metres

Let us now consider the train in its various positions during the braking :

Position I = Start of the brake application.

Position II = The head of the train has not yet reached the beginning of the element the gradient of which is i_2.

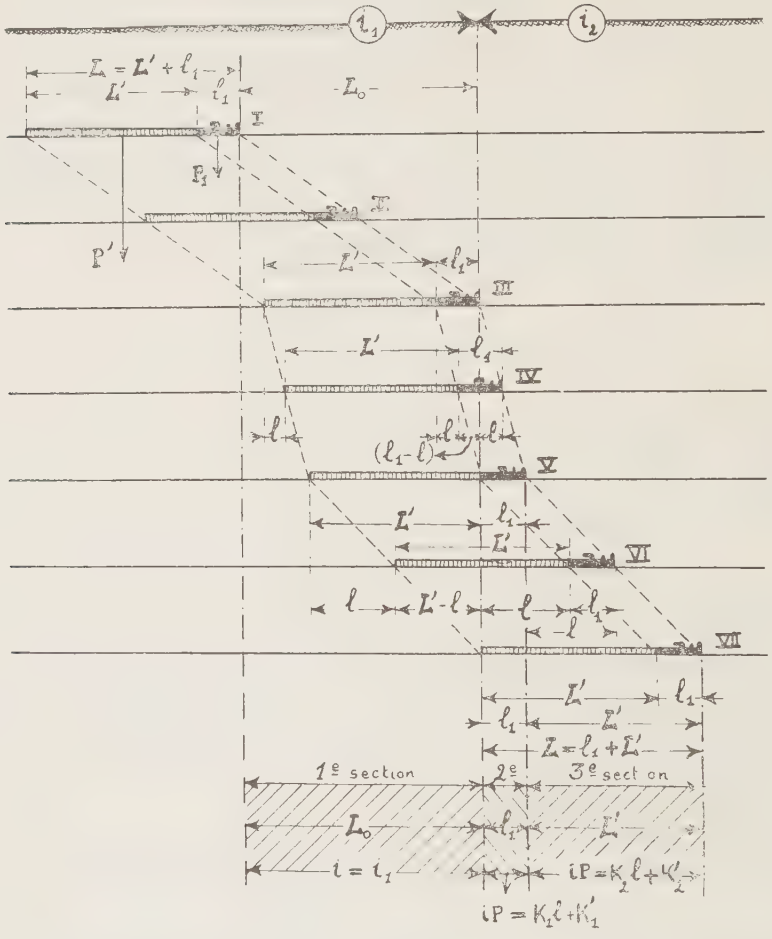

Fig. 1.

separates the front of the locomotive (front buffer beam) from the beginning of the element with a gradient of i_2.

Position III = The head of the train reaches the beginning of the element the gradient of which is i_2.

Position IV = The locomotive is on both elements i_1 and i_2.

Position V = The locomotive is solely on element i_2 whilst the head of the rake of wagons reaches the beginning of the gradient.

Position VI = The rake of wagons is on both gradients i_1 and i_2.

Position VII = The whole train is on gradient i_2.

Let us make the variable l indicate any distance run over by the train from a determined position of the latter.

We find that :

1) For positions I and III of the train and for every position such as II between I and II :

$$iP - i_1P \quad \text{constant.}$$

2) For each position of the train such as IV, between III and V :

$$\begin{aligned} iP &= i_1P' + i_1p_1(l_1 - l) + i_2p_1l \\ &= i_1P' + i_1p_1l_1 - i_1p_1l + i_2p_1l \\ &= (i_2 - i_1)p_1l + i_1P' + i_1p_1l_1 \\ &= (i_2 - i_1)p_1l + i_1P' + i_1P_1 \\ &= (i_2 - i_1)p_1l + i_1(P' + P_1) \\ &= (i_2 - i_1)p_1l + i_1P \end{aligned}$$

or if we designate the constants $(i_2 - i_1)p_1$ and i_1P by :

$$\begin{cases} K_1 = (i_2 - i_1)p_1 \\ K'_1 = i_1P \end{cases}$$

$$iP = K_1 l + K'_1$$

We shall find that when $l = l_1$:

$$\begin{aligned} iP &= (i_2 - i_1)p_1l_1 + i_1P \\ &= (i_2p_1l_1) - i_1p_1l_1 + i_1P \\ &= i_2P_1 - i_1P_1 + i_1P \\ &= i_2P_1 + i_1(P - P_1) \\ &= i_2P_1 + i_1P' \\ &= \text{the value for the position V.} \end{aligned}$$

3) For each position of the train such as VI between V and VII :

$$\begin{aligned} i\,P &= i_1p'(L' - l) + i_2p'l + i_2P_1 \\ &= i_1p'L' - i_1p'l + i_2p'l + i_2P_1 \\ &= (i_2 - i_1)p'l + i_1p'L' + i_2P_1 \\ &= (i_2 - i_1)p'l + i_1P' + i_2P_1 \end{aligned}$$

or if we designate the constants $(i_2 - i_1)p'$ and $(i_1P' - i_2P_1)$ by :

$$\begin{cases} K_2 = (i_2 - i_1)\,p' \\ K'_2 = i_1P' + i_2P_1 \end{cases}$$

$$iP = K_2 l + K'_2$$

We shall find that when $l = L'$:

$$\begin{aligned} iP &= (i_2 - i_1)\,p'L' + i_1P' + i_2P_1 \\ &= i_2p'L' - i_1p'L' + i_1P' + i_2P_1 \\ &= i_2P' - i_1P' + i_1P' + i_2P_1 \\ &= i_2P' + i_2P_1 \\ &= i_2(P' + P_1) \\ &= i_2P \\ &= \text{the value for the position VII.} \end{aligned}$$

***

In other words we see that everything occurs as though the mass M of the whole train weighing P tons subjected to the decelerative force from the braking and rolling resistance of the train and the action of gravity was concentrated in an actual point of the front buffer beam of the locomotive at the head of the train and as though this point progresses over a succession of imaginary « sections » each having a variable gradient

$$i = \frac{Kl + K'}{P}$$

the variable distance l being measured in the limits of each of these imaginary « sections » from its origin and the

constants K and K′ being those for each « section ».

In the case of the example considered everything occurs as if the said mass M concentrated on the front buffer beam of the locomotive (head of the train) ran over in turn :

1) A first « section » (I — III) of length $L = L_0$ metres with a true slope of $i_0 = i_1$.

2) A second « section » (III — V) of length $L_2 = l_1$ metres with a varying slope i such that :

$$iP = K_1 l + K'_1$$

a relation in which :

$$K_1 = (i_2 - i_1)p_1$$
$$K'_1 = i_1 P$$

3) A third « section » (V — VII), of length $L_3 = L'$ metres, with a varying slope i such that :

$$iP = K_2 l + K'_2$$

relation in which :

$$\left\{ \begin{array}{l} K_2 = (i_2 - i_1)p' \\ K'_2 = i_1 P' + i_2 P_1 \end{array} \right.$$

Note. — It will be clear that in the example selected, the train will stop before the « head of the train » has covered the distance L′ measured from the origin of the 3rd section. If it were not so, it would be necessary to consider a fourth section with a true slope of i_2.

***

From the principle developed above and in the limits of every imaginary « section » having a varying slope i, we find that the differential equation of the train can be written :

$$M \frac{dv}{dt} = -\left\{ fQ' + rP' + R + iP \right\}$$

$$= -\left\{ fQ' + rP' + R + Kl + K' \right\} \ldots \text{(I)}$$

a relation in which :

— The constant M = mass of the whole train including the factor of majoration η which takes account of the inertia question of the revolving masses of the wagons and locomotives

$$= \frac{1000 \times P \times \eta}{g}$$

— The constant P′ = the total weight (in tons) of the rake of wagons.

— The constants K and K′ :

= the parameters relating to the variable inclination of the imaginary slope considered (K in kilogram per lineal metre of the distance run and K′ in kg).

— The variable v :

= the speed of the train in metres per second.

— The variable t :

= the time in seconds measured from the instant the head of the train passes the origin of the « section » considered.

— The variable l :

= the distance in metres the train runs during the same time t.

— The variable Q′ :

= the instantaneous value (in kg) of the total force exerted by the brake shoes on the tyres of the braked wheels of the train;

= function of the total time passed from the origin of the braking.

— The variable f :

= the instantaneous value of the coefficient of friction of the brake blocks on the tyres;

= function of the speed.

— The variable r :

= the instantaneous value (kg per ton) of the specific rolling resistance of the wagons :

= function of the speed.

— The variable R :

= the instantaneous value (kg) of the overall resistance of the locomotive (or locomotives);

= function of the speed.

***

We will admit as previously that during a given run the coefficient of friction (f) of the brake blocks on the tyres varies as a function of the speed according to a linear law $f = a - bv$, the parameters a and b being governed by widely selected speed limits (see *Bulletin* of July 1946).

In the same way, we will admit that for each of the laws $r = \varphi(v)$ and $R = \Phi(v)$, we can substitute a linear law which, between the speed V_A of the train when the brake is applied and a speed close to zero, corresponds to a chord of each of the actual curves $r = \varphi(v)$ and $R = \Phi(v)$.

This enables us to write with a close enough approximation :

$$\left\{\begin{array}{l} r = r_0 + \dfrac{(r_A - r_0)v}{v_A} = r_0 + kv, \quad \text{with } k = \dfrac{r_A - r_0}{v_A} \\ R = R_0 + \dfrac{(R_A - R_0)v}{v_A} = R_0 + k'v, \quad \text{with } k' = \dfrac{R_A - R_0}{v_A} \end{array}\right.$$

relations in which.

v and v_A = speeds in metres per second.

r_A = specific resistance of the wagons at the speed v_A.

r_0 = the specific resistance of the same wagon at a speed close to zero.

R_A = the overall resistance of the locomotives hauling the rake at a speed v_A.

R_0 = the overall resistance of the same locomotives hauling the rake at a speed close to zero.

(These various resistances are given in the *Bulletin* of April 1948.)

***

In the last analysis from the above, within the limits of a given « section » *passed over by the head of the train*, the differential equation of the movement of the train itself can be written, remembering that the variables t and l are always measured from the beginning of the « section » considered :

$$M \frac{dv}{dt} = - \left\{ (a - bv) Q' + (r_0 + kv) P' + R_0 + k'v + Kl + K' \right\} \quad . \quad . \quad . \quad . \quad . \quad (II)$$

***

It would appear that the procedure to follow to solve the problem is the following :

1) Divide the journey — made by the head of the train during the braking — into a succession of *zones influenced by gravity* or « sections » with imaginary gradients, as by the example given above (see also the example given as an Appendix).

The beginning of the first « section » being marked by the position occupied by the head of the train at the instant the braking began, we get the distances L_1, L_2, L_3, etc., which respectively delimit the successive « sections ».

2) Calculate the relation $iP = \dot{K}l + K'$ characterising each of these « sections ».

3) Establish in the limit of each of them the differential equation (II).

4) Integrate these equations so as to obtain according to the case the relations $V = F(t)$ or $v = \varphi(l)$ for each « section ».

5) By these relations and starting from the speed $v_1 = v_A$ which characterises the start of the braking (beginning of the first « section ») calculate :

a) Firstly the speed v_2 of the head of the train at the end of the first « section » (start of the second « section »), speed which becomes v_1 in relation to this latter; then (starting from this speed v_1) the speed v_2 of the head of the train at the end of the second « section » and so on.

b) The corresponding time the head of the train takes to run over each « section » respectively.

6) Having proceeded in this way, step by step, starting from the speed v_A (speed at the start of braking) let us suppose we have found (Fig. 2) :

See example in the appendix	1st section	2nd section	3rd section	4th section
Length	L_1	L_2	L_3	L_4
Speed v_1	v_A	v_2	v_3	v_4
Speed v_2	v_2	v_3	v_4	v_5
Time	T_1	T_2	T_3	T_4

the speed v_5 being the speed of the train at the instant in which the head of the train reaches the beginning of the fifth « section », in which for example the head of the train is expected to stop.

7) Calculate, starting from this speed v_5, the final distance L_5 of the stop travelled by the head of the train over this last « section » as well as the corresponding time T_5.

8) The total distance of stop wanted will have as its value :

$$L_1 + L_2 + L_3 + L_4 + L_5$$

and corresponding length of time :

$$T_1 + T_2 + T_3 + T_4 + T_5$$

Note.

If as happens most often an imaginary braking at constant pressure (as for example the 3rd section in the case of Fig. 2) it is as well to proceed as follows (Fig. 3) :

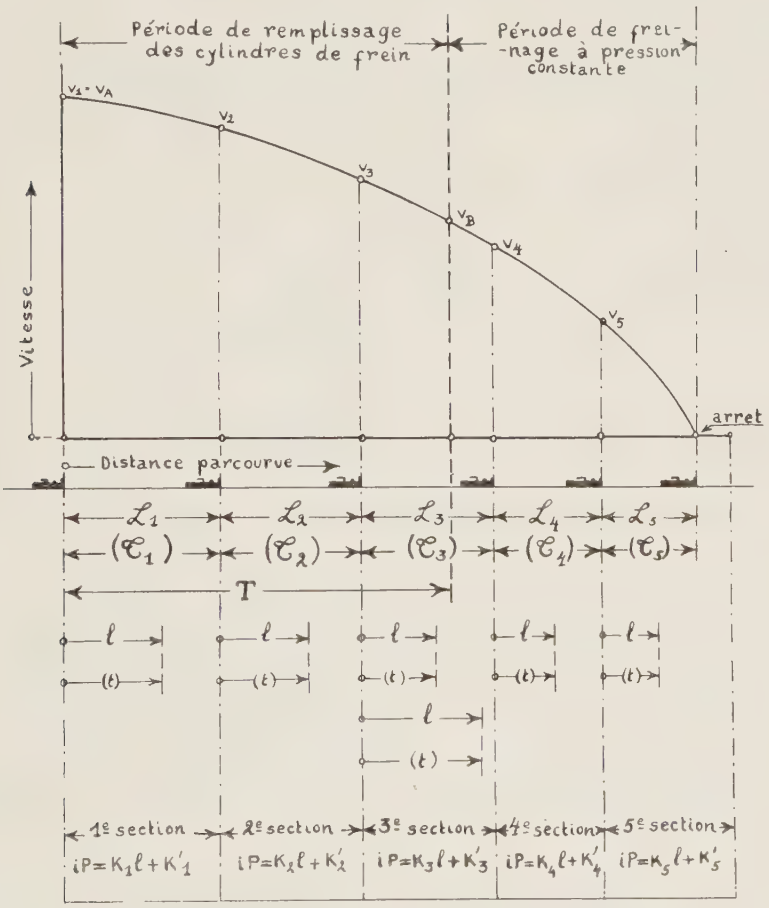

Fig. 2. — Diagram of speed and distance travelled.

Période de remplissage des cylindres de frein = Recharging period of brake cylinders. — Période de freinage à pression constante = Period of braking at constant pressure. — Vitesse = Speed. — Arrêt = Stop. — Distance parcourue = Distance travelled.

« section » wanders into the end of the period during which the brake cylinders refill and on to the start of the period of

1) Knowing by calculation of the speed v_3 of the train when its head runs onto the beginning of the « section » as well

N. B. The letters T (in italics) correspond to the greek letters τ (tau) used in Figs. 2 to 6_A.

as the time $(T_1 + T_2)$ passed since the braking began and consequently the time $t_3 = T - (T_1 + T_2)$ still available to the end of the period for refilling the brake cylinders, calculate :

2) Having in this way found this last speed and also the distance $l'_3 = L_3 - l_3$ to be travelled by the head of the train to get to the end of the « section », calculate :

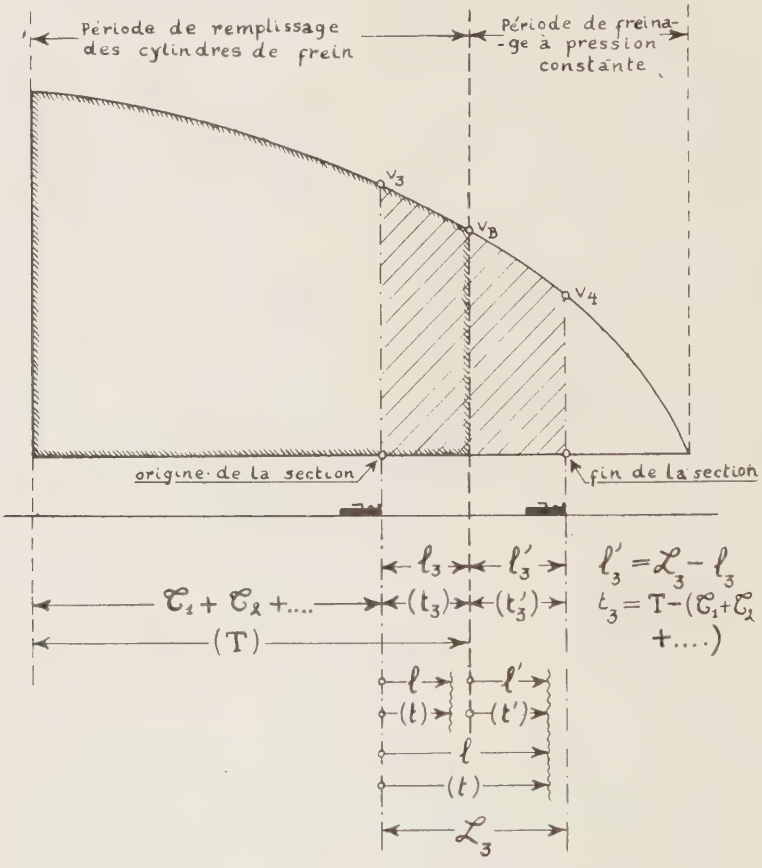

Fig. 3. — Diagram of speed and distance travelled.

Période de remplissage des cylindres de frein = Recharging period of brake cylinders. — Période de freinage à pression constante = Period of braking at constant pressure. — Origine de la section = Beginning of the section. — Fin de la section = End of the section.

a) the distance l_3 travelled by the head of the train during this time t_3;

b) the speed of the train after the time t_3, that is to say the speed v_B which characterises the end of the period to recharge the brake cylinders.

a) the time t'_3 taken by the head to travel the distance l'_3;

b) the speed v_4 which is that of the train at the moment its head reaches the end of the « section ».

CHAPTER II.

Integration of the differential equation of the movement of the train within the limits of a given « section ».

A. *Period of recharging the brake cylinders.*

We have seen (*Bulletin*, March 1948) that at any instant during the period Σq of the total brake application (designated by Q′) can be expressed by the relation :

$$Q' = Q - \frac{Q\,(T - T)^n}{T^n}$$

in which :

— The constant Q = the maximum value of the total force of application (in kg);

— The constant T = the period of refilling the brake cylinders (in seconds);

— The constant n = a numerical exponent (for example 2.5);

— The variable T = the time passed at a given moment since the braking began (in seconds).

If we designate by the constant T_0 the time (in seconds) from the beginning of braking until the head of the train gets to the beginning of a given « section » we can write (see fig. 4) :

$$T = T_0 + t$$

the variable t representing the time passed at any given moment from the instant at which the head of the train passed the origin of a section.

Under these conditions :

$$T - T = T - (T_o + t)$$
$$= T - T_o - t$$

or if we make $\Theta = T - T_o$:

$$T - T = \Theta - t$$

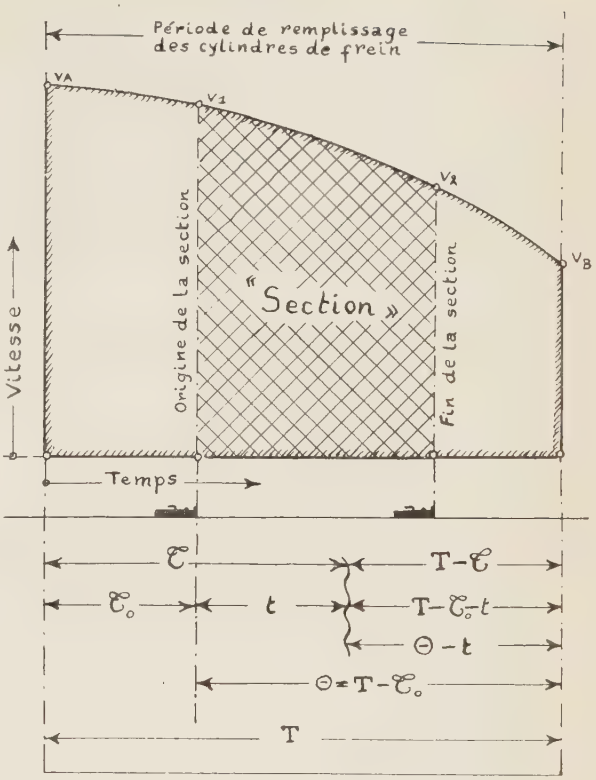

Fig. 4. — Speed and time diagram.

Période de remplissage des cylindres de frein = Recharging period of brake cylinders. — Vitesse = Speed. — Origine de la section. = Beginning of the section. — Fin de la section = End of the section. — Temps = Time.

so that we can also write :

$$Q' = Q - \frac{Q(\Theta - t)^n}{T^n}$$

Whence, in the limits of a given « section », passed over by the head of the train during the period the brake cylinders are being recharged, the differential equation of the motion of the train can be written :

$$M\frac{dv}{dt} = -\left\{(a - bv)\left[Q - \frac{Q(\Theta - t)^n}{T^n}\right] + (r_0 + kv)P' + R_0 + k'v + Kl + K'\right\}$$

or :

$$\frac{dv}{dt} = -\frac{1}{M}\left\{aQ - \frac{aQ}{T^n}(\Theta - t)^n - bQv + \frac{bQ}{T^n}(\Theta - t)^n v + r_0 P' + kP'v + R_0 + k'v + Kl + K'\right\}$$

$$= -\frac{1}{M}\left\{aQ - aQ\frac{(\Theta - t)^n}{T^n} - bQv + bQ\frac{(\Theta - t)^n}{T^n}v + (kP' + k')v + Kl + (r_0 P' + R_0 + K')\right\}$$

or, in making :

$$\begin{cases} A = aQ \\ B = bQ \\ C = kP' + k' \\ D = r_0 P' + R_0 + K' \end{cases}$$

$$\frac{dv}{dt} = -\frac{1}{M}\left\{A - A\frac{(\Theta - t)^n}{T^n} - Bv + B\frac{(\Theta - t)^n}{T^n}v + Cv + Kl + D\right\}$$

or finally :

$$\frac{dv}{dt} = -\frac{1}{M}\left\{A - A\frac{(\Theta - t)^n}{T^n} + B\frac{(\Theta - t)^n}{T^n}v + (C - B)v + Kl + D\right\} \quad . \quad . \qquad (III)$$

Integrating this differential equation on Mac-Laurin's theorem :

$$v - v_0 + F'(o)t + F''(o)\frac{t^2}{2!} + F'''(o)\frac{t^3}{3!} + F''''(o)\frac{t^4}{4!} + F'''''(o)\frac{t^5}{5!} + \quad . \quad . \quad . \quad .$$

$$= v_0 + F'(o)\,t + F''(o)\frac{t^2}{2} + F'''(o)\frac{t^3}{6} + F''''(o)\frac{t^4}{24} + F'''''(o)\frac{t^5}{120} + \quad . \quad . \quad . \quad . \qquad (0)$$

We know that the constant v_o indicates what the function $v = F(t)$ becomes when $t = 0$.

In the present case $v_0 = v_1$ as v_1 is the speed of the train at the moment the head of the train passes the origin of the « section ».

Seeing that $vdt = dl$

L_1 = length of the « section »;

T_1 = the time the head of the train takes to pass through the « section »;

v_2 = the speed of the train at the instant the head of the train gets to the end of the « section »;

the relation (0) gives :

$$dl = v_1\,dt + F'(o)\,t\,dt + F''(o)\,\frac{t^2}{2}\,dt + F'''(o)\,\frac{t^3}{6}\,dt + \ldots\ldots\ldots\ldots$$

whence :

$$\int_0^{L_1} dl = v_1 \int_0^{T_1} dt + F'(o) \int_0^{T_1} t\,dt + F''(o)\,\frac{1}{2} \int_0^{T_1} t^2\,dt + F'''(o)\,\frac{1}{6} \int_0^{T_1} t^3\,dt + \ldots$$

or :

$$L_1 = v_1\,T_1 + F'(o)\,\frac{T_1^2}{2} + F''(o)\,\frac{T_1^3}{6} + F'''(o)\,\frac{T_1^4}{24} + \ldots\ldots\ldots\ldots \qquad (1)$$

a relation which enables the time T_1 to be deduced as a function of the length L_1.

Substituting in the equation (0) the value of T_1 so found allows us to write :

$$v_2 = v_1 + F'(o)\,T_1 + \frac{1}{2}\,F''(o)\,T_1^2 + \frac{1}{6}\,F''(o)\,T_1^3 + \ldots\ldots\ldots\ldots \qquad (2)$$

If a section of time T_1 (taken in the limits of the time to run over a « section») were given, we could ascertain directly :

— by means of equation (1) = the distance L_1 run by the head of the train during the section of time T_1;

— by means of equation (2) — the speed v_2 of the train at the end of the same interval.

In this case the speed $v_1 = v_0$ corresponds to that of the train at the instant the head passes the beginning of the interval considered.

***

The values $F'(0)$ and $F''(o)$ are deduced easily from the differential equation (III) in noting that when $t = o$, we have simultaneously $l = o$ and $v_0 = v_1$.

In this way we find :

$$1)\ F'(o) = \left(\frac{dv}{dt}\right)_{\substack{t=0 \\ v=v_0}} = -\frac{1}{M}\left\{A - A\frac{\Theta n}{Tn} + B\frac{\Theta n}{Tn}v_0 + (C - B)v_0 + D\right\}$$

$$= -\frac{1}{M}\left\{A\left(1 - \frac{\Theta n}{Tn}\right) + B\frac{\Theta n}{Tn}v_0 + C\,v_0 - B\,v_0 + D\right\}$$

$$= -\frac{1}{M}\left\{A\left(1 - \frac{\Theta n}{Tn}\right) + B\,v_0\left(\frac{\Theta n}{Tn} - 1\right) + C\,v_0 + D\right\}$$

$$= -\frac{1}{M}\left\{A\left(1 - \frac{\Theta n}{Tn}\right) - B\,v_0\left(1 - \frac{\Theta n}{Tn}\right) + C\,v_0 + D\right\}$$

$$= -\frac{1}{M}\left\{\left(A - B\,v_0\right)\left(1 - \frac{\Theta n}{Tn}\right) + C\,v_0 + D\right\}$$

$$= -\frac{1}{M}\left\{\left(a - b\,v_0\right)\left(1 - \frac{\Theta n}{Tn}\right)Q + C\,v_0 + D\right\} \quad \ldots\ldots\ldots \quad (3)$$

Particular cases.

a) If the « section » has a constant gradient (i_0) and if the whole train is on it,

$$\begin{cases} K = o \\ K' = i_0 P \end{cases}$$

i_0 being the real inclination of the « section ». If we take D′ as the value taken in this case by the constant $D = r_0 P' + R_0 + K'$, namely :

$$D' = r_0 P' + R_0 + i_0 P$$

The relation (3) then becomes :

$$F'(o) = -\frac{1}{M}\left\{(a - b\,v_0)\left(1 - \frac{\Theta n}{Tn}\right)Q + C\,v_0 + D'\right\} \quad \ldots\ldots\ldots \quad (4)$$

b) If the start of the « section » corresponds to the beginning of the braking, that is to say if $T_0 = 0$, so that $\Theta = T - T_0 = T - 0 = T$, the formula (3) becomes :

$$F'(o) = -\frac{1}{M}\left\{(a - bv_0)\left(1 - \frac{T^n}{T^n}\right)Q + C\,v_0 + D\right\}$$

$$= -\frac{1}{M}\left\{Cv_0 + D\right\} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (5)$$

c) If, at the same time $K = o$

$$F'(o) = -\frac{1}{M}\left\{Cv_0 + D'\right\} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (6)$$

2) As $\frac{dl}{dt} = v$:

$$F''(t) = \frac{d^2v}{dt^2} = -\frac{1}{M}\left\{n\,A\,\frac{(\Theta - t)^{n-1}}{T^n} - n\,B\,\frac{(\Theta - t)^{n-1}}{T^n}\,v + B\,\frac{(\Theta - t)^n}{T^n}\,\frac{dv}{dt} + (C - B)\,\frac{dv}{dt} + Kv\right\}$$

$$= -\frac{1}{M}\left\{n\,\frac{(\Theta - t)^{n-1}}{T^n}(A - Bv) + B\,\frac{(\Theta - t)^n}{T^n}\,\frac{dv}{dt} + (C - B)\,\frac{dv}{dt} + Kv\right\}$$

$$= -\frac{1}{M}\left\{n\,(A - Bv)\,\frac{(\Theta - t)^{n-1}}{T^n} + B\,\frac{(\Theta - t)^n}{T^n}\,\frac{dv}{dt} + C\,\frac{dv}{dt} - B\,\frac{dv}{dt} + Kv\right\}$$

$$= -\frac{1}{M}\left\{n\,(A - Bv)\,\frac{(\Theta - t)^{n-1}}{T^n} + B\left[\frac{(\Theta - t)^n}{T^n} - 1\right]\frac{dv}{dt} + C\,\frac{dv}{dt} + Kv\right\}$$

$$= -\frac{1}{M}\left\{n\,(A - Bv)\,\frac{(\Theta - t)^{n-1}}{T^n} - B\left[1 - \frac{(\Theta - t)^n}{T^n}\right]\frac{dv}{dt} + C\,\frac{dv}{dt} + Kv\right\}$$

$$= -\frac{1}{M}\left\{n\,(A - Bv)\,\frac{(\Theta - t)^{n-1}}{T^n} + \left[C - B\left[1 - \frac{(\Theta - t)^n}{T^n}\right]\right]\frac{dv}{dt} + Kv\right\}$$

$$= -\frac{1}{M}\left\{n\,(a - bv)\,\frac{(\Theta - t)^{n-1}}{T^n}\,Q + \left[C - bQ\left[1 - \frac{(\Theta - t)^n}{T^n}\right]\right]F'(t) + Kv\right\}$$

Whence :

$$F''(o) = \left(\frac{d^2v}{dt^2} \right)_{\substack{t=0 \\ v=v_0}} = -\frac{1}{M} \left\{ n\,(a - bv_0) \frac{\Theta^{n-1}}{T^n} Q + \left[C - bQ \left(1 - \frac{\Theta^n}{T^n} \right) \right] F'(o) + Kv_0 \right\} \quad . \quad . \quad . \quad . \quad . \quad (7)$$

when $F'(o) = (3)$.

Particular cases.

a) **If K = 0**

$$F''(o) = -\frac{1}{M} \left\{ n\,(a - bv_0) \frac{\Theta^{n-1}}{T^n} Q + \left[C - bQ \left(1 - \frac{\Theta^n}{T^n} \right] F'(o) \right\} \quad . \quad . \quad . \quad . \quad (8)$$

when $F'(o) = (4)$.

b) **If $T_0 = 0$,** so that $\Theta = T$.

$$F''(o) = -\frac{1}{M} \left\{ n\,(a - bv_0) \frac{T^{n-1}}{T^n} Q + \left[C - bQ \left(1 - \frac{T^n}{T^n} \right) \right] F'(o) + Kv_0 \right\}$$

$$-\frac{1}{M} \left\{ \frac{n\,(a - bv_0)Q}{T} + \left[C - bQ\,(1 - 1) \right] F'(o) + Kv_0 \right\}$$

$$= -\frac{1}{M} \left\{ \frac{n\,(a - bv_0)Q}{T} + C\,F'(o) + Kv_0 \right\} \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (9)$$

when $F'(o) = (5)$.

c) **If $T_0 = 0$** and if, at the same time, **K = 0**.

$$F''(o) = -\frac{1}{M} \left\{ \frac{n\,(a - bv_0)\,Q}{T} + C\,F'(o) \right\} \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (10)$$

when $F'(o) = (6)$.

Note.

If however a « section » is rather long (if, for example it is several hundred metres in length as in the numerical application treated at the end of this second part) it is necessary if the convergent series (1) and (2) are to reach values sufficiently close to one another to calculate $F'''(o)$ $F''''(o)$ and even $F'''''(o)$.

Now in the present case which is that of a function of several variables, this calculation necessitates developments of which the least we can say is that they are most laborious. Such developments consequently would be beyond the scope of this study.

A satisfactory result however can be obtained without it being necessary to have recourse to derivatives above the second order provided we work in sufficiently small intervals (5 to 10 seconds), which gets round the difficulty. (See numerical example quoted above).

B. *Braking period under constant pressure.*

First hypothesis.

The train continues to run without any of the wheels of the braked vehicles of the train being locked (skidding).

The total force applying the brake blocks against the tyres being constant and equal to the maximum force Q kilogrammes, the differential equation of the motion of the train applicable within the limits of an imaginary « section » passed over by the head of the train during the period considered becomes :

$$M\frac{dv}{dt} = -\left\{(a - bv)\,Q + (r_0 + kv)\,P' + (R_0 + k'v) + iP\right\}$$

$$= -\left\{aQ - bQv + r_0 P' + kP'v + R_0 + k'v + Kl + K'\right\}$$

$$= -\left\{(kP' + k' - bQ)v + Kl + (aQ + r_0 P' + R_0 + K')\right\}$$

whence :

$$\frac{dv}{dt} = -\left\{\frac{(kP' + k' - bQ)}{M}v + \frac{K}{M}l + \frac{aQ + r_0 P' + R_0 + K'}{M}\right\}$$

or :

$$\frac{dv}{dt} = -\left\{ Av + Bl + C \right\}$$

taking :

$$A = \frac{kP' + k' - bQ}{M}$$

$$B = \frac{K}{M}$$

$$C = \frac{aQ + r_0 P' + R_0 + K'}{M}$$

or, as $\frac{dv}{dt} = v \frac{dv}{dl}$:

$$v \frac{dv}{dl} = -\left\{ Av + Bl + C \right\} \quad . \quad . \quad . \text{(IV)}$$

a differential equation which has to be integrated so as to be able to get v as a function of l.

We see that this equation is of the form :

$$y \frac{dy}{dx} = -\left\{ Ay + Bx + C \right\}$$

or :

$$y\,dy + Ay\,dx + Bx\,dx + C\,dx = 0$$

or :

$$y\,dy + (Ay + Bx + C)\,dx = 0$$

To make this equation homogeneous let : $x = X + \alpha$

whence : $X = x - \alpha$ and consequently: $dX = dx$.

The equation becomes :

$$y\,dy + [Ay + B(X + \alpha) + C]\,dX = 0$$

or :

$$y\,dy + [Ay + BX + B\alpha + C]\,dX = 0$$

If $B\alpha + C = 0$, we shall have :

$$\alpha = -\frac{C}{B}$$ and the equation becomes :

$$y\,dy + (Ay + BX)\,dX = 0$$

or :

$$y\,dy + Ay\,dX + BX\,dX = o$$

a homogeneous equation.

Now make :

$y = Xs$, whence $s = \frac{y}{X}$, and $dy = Xds + s\,dX$.

In these conditions the equation becomes :

$$Xs\,(X\,ds + s\,dX) + (AXs + BX)\,dX = 0$$

or, dividing member by member by X :

$$s\,(X\,ds + s\,dX) + (As + B)\,dX = 0$$

or :

$$X.s.ds + s^2\,dX + As\,dX + B\,dX = 0$$

or :

$$s^2\,dX + As\,dX + B\,dX = -Xs\,ds$$

or :

$$(s^2 + As + B)\,dX = -Xs\,ds$$

whence :

$$\frac{dX}{X} = -\frac{s\,ds}{s^2 + As + B} \quad . \quad . \quad . \quad . \quad . \quad . \text{(V)}$$

whence :

$$\int_{x_1}^{x_2} \frac{dX}{X} = -\int_{s_1}^{s_2} \frac{s\,ds}{s^2 + As + B}$$

or :

$$\left[\log_n X\right]_{x_1}^{x_2} = -\int_{s_1}^{s_2} \frac{s\,ds}{s^2 + As + B}$$

Replacing X by its value :

$$X = x - \alpha = x - \left(-\frac{C}{B}\right) = x + \frac{C}{B}$$

we get finally :

$$\left[\log_n \left(x + \frac{C}{B}\right)\right]_{x_1}^{x_2} = -\int_{s_1}^{s_2} \frac{s\,ds}{s^2 + As + B}$$

As regards $\int_{s_1}^{s_2} \frac{s\,ds}{s^2 + As + B}$, we know there are three cases to consider:

1st *case*. If $\frac{A^2}{4} - B > 0$, let :

$$\left\{\begin{array}{l} \sqrt{\frac{A^2}{4} - B} = \Delta \\ \Delta + \frac{A}{2} = -\alpha, \text{ when } \alpha = -\left(\Delta + \frac{A}{2}\right) \\ \Delta - \frac{A}{2} = \beta \end{array}\right.$$

We find :

$$\left[\log_n x + \frac{C}{B}\right]_{x_1}^{x_2} = -\int_{s_1}^{s_2} \frac{s\,ds}{s^2 + As + B}$$

$$= -\frac{1}{2\Delta}\left\{-\alpha \log_n \frac{\alpha - s_2}{\alpha - s_1} + \beta \log_n \frac{\beta - s_2}{\beta - s_1}\right\}$$

2nd *case*. If $\frac{A^2}{4} - B < 0$, let $\sqrt{B - \frac{A^2}{4}} = \Theta$

We find :

$$\left[\log_n (x + \frac{C}{B})\right]_{x_1}^{x_2} = -\int_{s_1}^{s_2} \frac{s\,ds}{s^2 + As + B}$$

$$= -\left\{-\frac{1}{2}\log_n \frac{\left(s_1 + \frac{A}{2}\right)^2 + \Theta^2}{\left(s_2 + \frac{A}{2}\right)^2 + \Theta^2} + \frac{A}{2\Theta} \text{ arc tg } \frac{\Theta\,(s_1 - s_2)}{\Theta^2 + \left(s_1 + \frac{A}{2}\right)\left(s_2 + \frac{A}{2}\right)}\right\}$$

$$= \frac{1}{2}\log_n \frac{\left(s_1 + \frac{A}{2}\right)^2 + \Theta^2}{\left(s_2 + \frac{A}{2}\right)^2 + \Theta^2} - \frac{A}{2\Theta} \text{ arc tg } \frac{\Theta\,(s_1 - s_2)}{\Theta^2 + \left(s_1 + \frac{A}{2}\right)\left(s_2 + \frac{A}{2}\right)}$$

3rd *case*. If $\frac{A^2}{4} - B = 0$, we find :

$$\left[\log_n \left(x + \frac{C}{B}\right)\right]_{x_1}^{x_2} = -\int_{s_1}^{s_2} \frac{s\,ds}{s^2 + As + B} = -\frac{1}{2}\left[\frac{A}{s_2 + \frac{A}{2}} - \frac{B}{s_1 + \frac{A}{2}} - 2\log_n \frac{s_1 + \frac{A}{2}}{s_2 + \frac{A}{2}}\right]$$

As regards the limits of integration :

$$x_1,\ x_2,\ s_1,\ s_2$$

let us remember that the independently variable x corresponds here to the instantaneous value l of the distance run over by the head of the train from the instant it passed the beginning of the section $s = \frac{y}{X}$

v_1 = the speed of the train at the instant at which the head of the train crosses the origin of the section;

v_2 = the speed of the train at the instant the same head reaches the end of the section : we shall obtain :

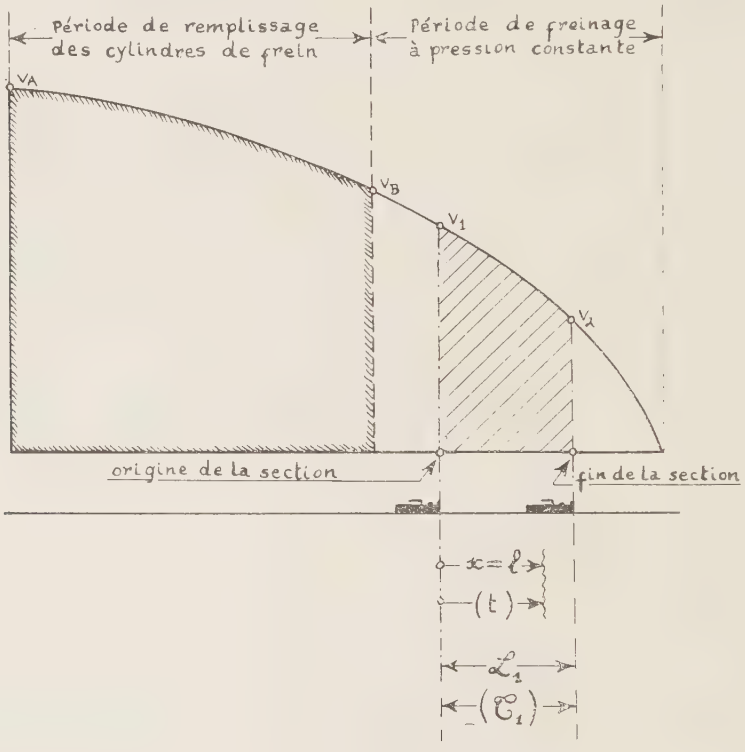

Fig. 5, A — Diagram of speed and distance travelled.

Période de remplissage des cylindres de frein = Recharging period of brake cylinders. — Période de freinage à pression constante = Period of braking at constant pressure. — Origine de la section = Beginning of the section. — Fin de la section = End of the section.

$= \dfrac{v}{x + \dfrac{C}{B}}$, so that here : $s = \dfrac{v}{l + \dfrac{C}{B}}$

Under these conditions (See Fig. 5A),

L_1 = the length of the section (known distance);

$$\begin{cases} x_1 = o \\ x_2 = L_1 \end{cases}$$

$$\begin{cases} s_1 = \dfrac{v_1}{x_1 + \dfrac{C}{B}} = \dfrac{v_1}{0 + \dfrac{C}{B}} = \dfrac{v_1}{\dfrac{C}{B}} = \dfrac{B\,v_1}{C} \\ s_2 = \dfrac{v_2}{x_2 + \dfrac{C}{B}} = \dfrac{v_2}{L_1 + \dfrac{C}{B}} \end{cases}$$

relations in which :

$$\frac{C}{B} = \frac{aQ + r_0 P' + R_0 + K'}{K} \text{ and } \frac{B}{C} = \frac{K}{aQ + r_0 P' + R_0 + K'}$$

Calculation of the speed.

1) **If** $\frac{A^2}{4} - B > 0$:

$$\left[\log_n\left(x + \frac{C}{B}\right)\right]_{x_1 = 0}^{x_2 = L_1} = -\frac{1}{2\Delta}\left\{-\alpha \log_n \frac{\alpha - \frac{v_2}{L_1 + \frac{C}{B}}}{\alpha - \frac{Bv_1}{C}} + \beta \log_n \frac{\beta - \frac{v_2}{L_1 + \frac{C}{B}}}{\beta - \frac{Bv_1}{C}}\right\}$$

or :

$$\log_n\left(L_1 + \frac{C}{B}\right) - \log_n \frac{C}{B} = \frac{\alpha}{2\Delta} \log_n \frac{\alpha - \frac{v_2}{L_1 + \frac{C}{B}}}{\alpha - \frac{Bv_1}{C}} - \frac{\beta}{2\Delta} \log_n \frac{\beta - \frac{v_2}{L_1 + \frac{C}{B}}}{\beta - \frac{Bv_1}{C}} \quad (11)$$

equation which gives v_2 in terms of v_1.

In the particular case in which the speed v_2 cancels itself out (the train stops) the final stopping distance l_1 (Fig. 5B) travelled on the section by the head of the train, from the beginning of the section, is easily deduced from the relation :

$$\log_n\left(l_1 + \frac{C}{B}\right) - \log_n \frac{C}{B} = \frac{\alpha}{2\Delta} \log_n \frac{\alpha}{\alpha - \frac{Bv_1}{C}} - \frac{\beta}{2\Delta} \log_n \frac{\beta}{\beta - \frac{Bv_1}{C}} \quad (12)$$

2) **If** $\frac{A^2}{4} - B < 0$:

$$\log_n\left(L_1 + \frac{C}{B}\right) - \log_n \frac{C}{B} = \frac{1}{2} \log_n \frac{\left(\frac{Bv_1}{C} + \frac{A}{2}\right)^2 + \Theta^2}{\left(\frac{v_2}{L_1 + \frac{C}{B}} + \frac{A}{2}\right)^2 + \Theta^2} -$$

$$- \frac{A}{2\Theta} \text{ arc tg } \frac{\Theta\left(\frac{Bv_1}{C} - \frac{v_2}{L_1 + \frac{C}{B}}\right)}{\Theta^2 + \left(\frac{Bv_1}{C} + \frac{A}{2}\right)\left(\frac{v_2}{L_1 + \frac{C}{B}} + \frac{A}{2}\right)} \quad (13)$$

equation which gives v_2 in terms of v_1.

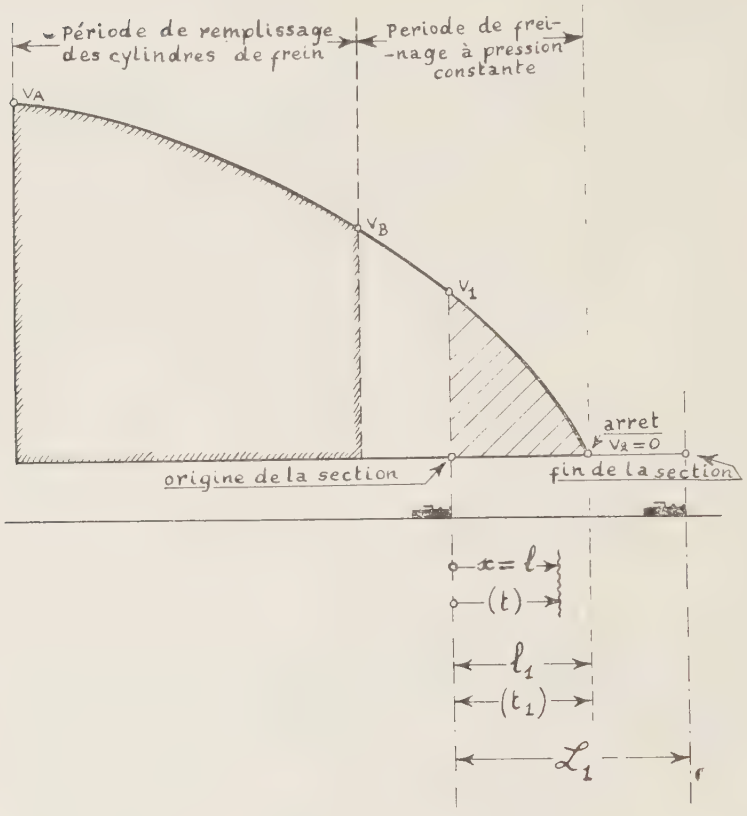

Fig. 5, B. — Diagram of speed and distance travelled.

Période de remplissage des cylindres de frein = Recharging period of brake cylinders. — Période de freinage à pression constante = Period of braking at constant pressure. — Origine de la section = Beginning of the section. — Arrêt = Stop. — Fin de la section = End of the section.

In the particular case in which v_2 cancels out (the train stops) the distance l_1 is readily deduced from the formula :

$$\log_n\left(l_1 + \frac{C}{B}\right) - \log_n \frac{C}{B} = \frac{1}{2} \log_n \frac{\left(\frac{Bv_1}{C} + \frac{A}{2}\right)^2 + \Theta^2}{\frac{A^2}{4} + \Theta^2} - \frac{A}{2\Theta} \operatorname{arc\,tg} \frac{\Theta \frac{Bv_1}{C}}{\Theta^2 + \left(\frac{Bv_1}{C} + \frac{A}{2}\right)\frac{A}{2}} \quad \ldots\ldots \quad (14)$$

3) **If** $\frac{A^2}{4} - B = 0$:

$$\log_n\left(L_1 + \frac{C}{B}\right) - \log_n \frac{C}{B} = -\frac{1}{2}\left[\frac{A}{\frac{v_2}{L_1 + \frac{C}{B}} + \frac{A}{2}} - \frac{B}{\frac{Bv_1}{C} + \frac{A}{2}} - 2\log_n \frac{\frac{Bv_1}{C} + \frac{A}{2}}{\frac{v_2}{L_1 + \frac{C}{B}} + \frac{A}{2}}\right] \quad \ldots\ldots\ldots \quad (15)$$

equation giving v_2 as a function of v_1.

In the particular case in which the speed v_2 cancels out (the train stops) the distance l_1 is readily deduced from the equation :

$$\log_n\left(l_1 + \frac{C}{B}\right) - \log_n \frac{C}{B} = -\frac{1}{2}\left[\frac{A}{\frac{A}{2}} - \frac{B}{\frac{Bv_1}{C} + \frac{A}{2}} - 2\log_n \frac{\frac{Bv_1}{C} + \frac{A}{2}}{\frac{A}{2}}\right]$$

$$= -1 + \frac{B}{\frac{2\,Bv_1}{C} + A} + \log_n \frac{\frac{Bv_1}{C} + \frac{A}{2}}{\frac{A}{2}} \quad \ldots \quad (16)$$

Case in which the section overlaps the end of the period during which the brake cylinders are being recharged and the start of the period of braking at constant pressure (Fig. 6A) in such a way that the speed v_1 is here the speed v_B characteristic of the end of the recharging period.

The time t being measured from the instant the head of the train crosses the beginning of the « section », let us represent by :

1) The constant L_1 = the length (known) of the « section ».

2) The constant l_0 = the distance (known) run by the head of the train from the origin of the section to the instant at which the period of braking at constant pressure begins.

3) The constant $L'_1 = L_1 - l_0$ (known distance).

4) The constant t_0 = the time (known) the head of the train takes to run the distance l_0.

5) The variable l = the distance trav-

elled by the head of the train on the section from the beginning to the instant t.

6) The variable l' = the distance travelled by the head of the train over the section from the start of the period of constant pressure braking to the instant t.

whilst :

$$iP = Kl + K'$$
$$= K(l' + l_0) + K'$$
$$= Kl' + Kl_0 + K'$$

Therefrom, and in the limits between the origin of the constant pressure braking and the instant when the head of the train

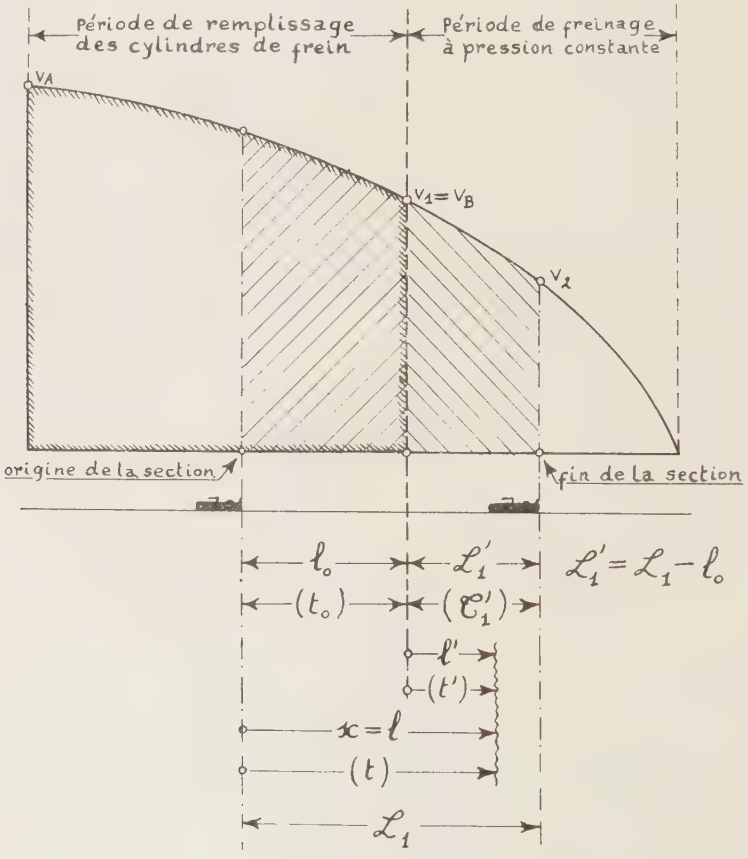

Fig. 6, A. — Diagram of speed and distance travelled.

Période de remplissage des cylindres de frein = Recharging period of brake cylinders. — Période de freinage à pression constante = Period of braking at constant pressure. — Origine de la section = Beginning of the section. — Fin de la section = End of the section.

7) The variable t' = the time to travel this distance.

Under these conditions :

$$\begin{cases} l = l_0 + l', \text{ so that } dl = dl' \\ t = t_0 + t', \text{ so that } dt = dt' \end{cases}$$

reaches the end of the section considered (that is between the limits of the movement of the head of the train over the section of length $L'_1 = L_1 - l_0$) the differential equation of the movement of the train can be written :

$$M\frac{dv}{dt'} = -\left\{(a - bv)Q + (r_0 + kv)P' + (R_0 + k'v) + iP\right\}$$

$$= -\left\{aQ - bQv + r_0P' + kP'v + R_0 + k'v + Kl' + Kl_0 + K'\right\}$$

$$= -\left\{(kP' + k' - bQ)v + Kl' + (aQ + r_0P' + R_0 + Kl_0 + K'\right\}$$

whence :

$$\frac{dv}{dt'} = -\left\{\frac{(kP' + k' - bQ)v}{M} + \frac{K}{M}l' + \frac{aQ + r_0P' + R_0 + Kl_0 + K'}{M}\right\}$$

We have already taken :

$$A = \frac{kP' + k' - bQ}{M}$$

$$B = \frac{K}{M}$$

Let us now take :

$$C' = \frac{aQ + r_0P' + R_0 + Kl_0 + K'}{M}$$

and we get :

$$\frac{dv}{dt'} = -\left\{Av + Bl' + C'\right\}$$

or :

$$v\frac{dv}{dl'} = -\left\{Av + Bl' + C'\right\} \quad . \quad . \quad VI$$

The differential equation the integration of which gives the same results as those obtained by the integration of equation IV.

The limits of integration here are however :

$$\begin{cases} x_1 = 0 \\ x_2 = L'_1 \end{cases}$$

$$\begin{cases} s_1 = \dfrac{Bv_1}{C'} \\ s_2 = \dfrac{v_2}{L'_1 + \dfrac{C'}{B}} \end{cases}$$

relations in which $L'_1 = L_1 - l_0$ and $v_1 = v_0$.

1) **If** $\dfrac{A^2}{4} - B > 0$:

$$\log_n\left(L'_1 + \frac{C'}{B}\right) - \log_n\frac{C'}{B} = \frac{\alpha}{2\Delta}\log_n\frac{\alpha - \dfrac{v_2}{L'_1 + \dfrac{C'}{B}}}{\alpha - \dfrac{Bv_1}{C'}} - \frac{\beta}{2\Delta}\log_n\frac{\beta - \dfrac{v_2}{L'_1 + \dfrac{C'}{B}}}{\beta - \dfrac{Bv_1}{C_1}} \quad . \quad . \quad . \quad . \quad (17)$$

equation giving v_2 in terms of v_1.

In the particular case in which v_2 cancels out, if we designate by l'_1 (Fig. 6B) the final stopping distance travelled on the « section » by the head of the train from the origin

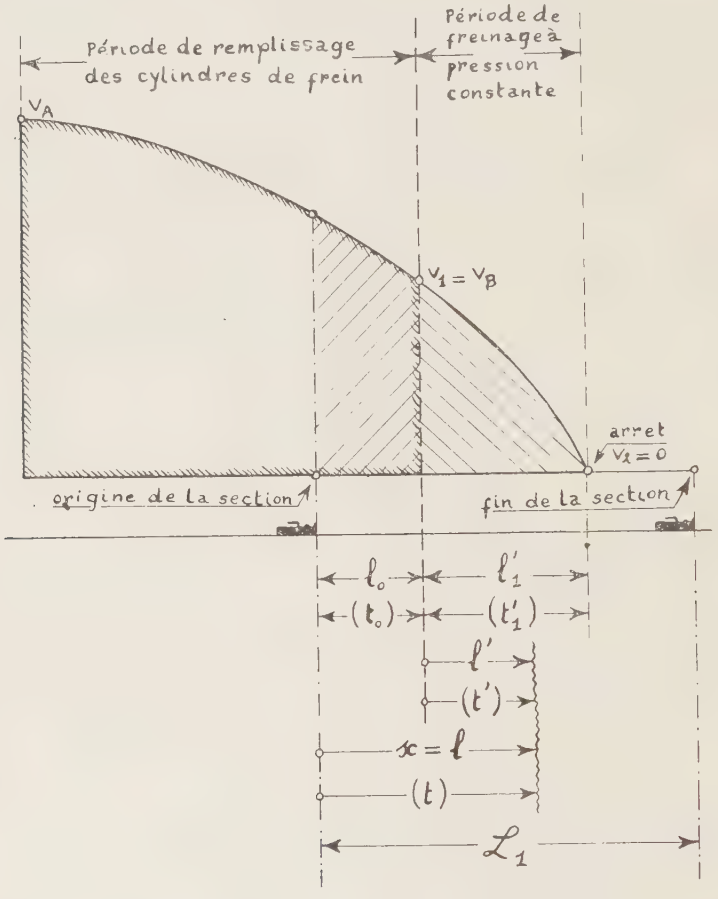

Fig. 6B. — Diagram of speed and distance travelled.

Période de remplissage des cylindres de frein = Recharging period of brake cylinders. — Période de freinage à pression constante = Period of braking at constant pressure. — Origine de la section = Beginning of the section. — Fin de la section = End of the section.

of the constant pressure braking period, this distance l'_1 is readily deduced from the relation :

$$\log_n \left(l'_1 + \frac{C'}{B} \right) - \log_n \frac{C'}{B} = \frac{\alpha}{2\Delta} \log_n \frac{\alpha}{\alpha - \frac{Bv_1}{C'}} - \frac{\beta}{2\Delta} \log_n \frac{\beta}{\beta - \frac{Bv_1}{C'}} \quad . \quad . \quad . \quad . \quad (18)$$

2) **If** $\frac{A^2}{4} - B < 0$:

$$\log_n\left(L'_1 + \frac{C'}{B}\right) - \log_n\frac{C'}{B} = \frac{1}{2}\log_n \frac{\left(\frac{Bv_1}{C'} + \frac{A}{2}\right)^2 + \Theta^2}{\left(\frac{v_2}{L'_1 + \frac{C'}{B}} + \frac{A}{2}\right) + \Theta^2}$$

$$- \frac{A}{2\Theta} \operatorname{arc\,tg} \frac{\Theta\left(\frac{Bv_1}{C'} - \frac{v_2}{L'_1 + \frac{C'}{B}}\right)}{\Theta^2 + \left(\frac{Bv_1}{C'} + \frac{A}{2}\right)\left(\frac{v_2}{L'_1 + \frac{C'}{B}} + \frac{A}{2}\right)} \quad \ldots\ldots \quad (19)$$

equation giving v_2, in terms of v_1.

In the particular case in which v_2 cancels out :

$$\log_n\left(l'_1 + \frac{C'}{B}\right) - \log_n\frac{C'}{B} = \frac{1}{2}\log_n \frac{\left(\frac{Bv_1}{C'} + \frac{A}{2}\right)^2 + \Theta^2}{\frac{A^2}{4} + \Theta^2}$$

$$- \frac{A}{2\Theta} \operatorname{arc\,tg} \frac{\Theta\frac{Bv_1}{C'}}{\Theta^2 + \left(\frac{Bv_1}{C'} + \frac{A}{2}\right)\frac{A}{2}} \quad \ldots\ldots\ldots\ldots \quad (20)$$

3) **If** $\frac{A^2}{4} - B = 0$:

$$\log_n\left(L'_1 + \frac{C'}{B}\right) - \log_n\frac{C'}{B} = -\frac{1}{2}\left[\frac{A}{\frac{v_2}{L'_1 + \frac{C'}{B}} + \frac{A}{2}} + \frac{B}{\frac{Bv_1}{C'} + \frac{A}{2}}\right.$$

$$\left. - 2\log_n \frac{\frac{Bv_1}{C'} + \frac{A}{2}}{\frac{v_2}{L'_1 + \frac{C'}{B}} + \frac{A}{2}}\right] \quad \ldots \quad \ldots\ldots\ldots \quad (21)$$

In the particular case in which v_2 cancels itself :

$$\log_n\left(l'_1 + \frac{C'}{B}\right) - \log_n \frac{C'}{B} = -1 + \frac{B}{\dfrac{2\,Bv_1}{C'} + A} + \log_n \frac{\dfrac{Bv_1}{C'} + \dfrac{A}{2}}{\dfrac{A}{2}} \quad . \quad . \quad . \qquad (22)$$

Calculation of the time.

a) *In the case in which the « section » does not overlap the two periods,* if we designate by :

T_1 = the time the head of the train takes to pass the « section » (Fig. 5A);

t_1 = the time the head of the train takes to travel the final stopping distance l_1 (Fig. 5B);

b) *In the case in which the « section » overlaps the two periods,* if we designate by :

t_0 = the time the head of the train takes to run the distance l_0 (Fig. 6A and 6B);

T'_1 = the time taken by the head of the train to run the distance $L'_1 = L_1 - l_0$ (Fig. 6A);

t'_1 = the time taken by the head of the train to run the final stopping distance l'_1 (fig. 6B);

these different values can be found by integrating the differential equation (V) :

$$\frac{dX}{X} = -\frac{s\,ds}{s^2 + As + B}$$

in which :

$$\begin{cases} dX = dl = v\,dt \\ X = l + \dfrac{C}{B} \text{ et } s = \dfrac{v}{l + \dfrac{C}{B}} \end{cases}$$

whence :

$$X = \frac{v}{s} \text{ and consequently}$$

$$\frac{dX}{X} = \frac{dl}{\dfrac{v}{s}} = \frac{v\,dt}{\dfrac{v}{s}} = s\,dt$$

so that :

$$\frac{dX}{X} = s\,dt = -\frac{s\,ds}{s^2 + As + B}$$

whence :

$$dt = -\frac{ds}{s^2 + As + B}$$

whence :

$$T_1 = \int_0^{T_1} dt = -\int_{s_1}^{s_2} \frac{ds}{s^2 + As + B}$$

1) **If** $\frac{A^2}{4} - B > 0$,

$$\int_{s_1}^{s_2} \frac{ds}{s^2 + As + B} = -\frac{1}{2\Delta}\left[\log_n \frac{-\alpha + s}{\beta - s}\right]_{s_1}^{s_2}$$

$$= -\frac{1}{2\Delta}\left[\log_n \frac{-\alpha + s_2}{\beta - s_2} - \log_n \frac{-\alpha + s_1}{\beta - s_1}\right]$$

$$= -\frac{1}{2\Delta}\left[\log_n (-\alpha + s_2) - \log_n (\beta - s_2) - \log_n (-\alpha + s_1) + \log_n (\beta - s_1)\right]$$

$$= -\frac{1}{2\Delta}\left[\log_n \frac{-\alpha + s_2}{-\alpha + s_1} + \log_n \frac{\beta - s_1}{\beta - s_2}\right]$$

$$= -\frac{1}{2\Delta}\left[\log_n \frac{\alpha - s_2}{\alpha - s_1} - \log_n \frac{\beta - s_2}{\beta - s_1}\right]$$

whence :

$$T_1 = -\int_{s_1}^{s_2} \frac{ds}{s^2 + As + B}$$

$$= +\frac{1}{2\Delta}\left[\log_n \frac{\alpha - s_2}{\alpha - s_1} - \log_n \frac{\beta - s_2}{\beta - s_1}\right]$$

If the section considered does not overlap the recharging period and that of constant pressure braking :

$$T_1 = \frac{1}{2\Delta}\left[\log_n \frac{\alpha - \dfrac{v_2}{L_1 + \dfrac{C}{B}}}{\alpha - \dfrac{Bv_1}{C}} - \log_n \frac{\beta - \dfrac{v_2}{L_1 + \dfrac{C}{B}}}{\beta - \dfrac{Bv_1}{C}}\right] \quad \ldots\ldots\ldots \quad (23)$$

In the case in which v_2 cancels out (the train stops) :

$$t_1 = \frac{1}{2\Delta}\left[\log_n \frac{\alpha}{\alpha - \frac{Bv_1}{C}} - \log_n \frac{\beta}{\beta - \frac{Bv_1}{C}}\right] \quad \ldots\ldots\ldots\ldots \quad (24)$$

If it overlaps the two periods :

$$T'_1 = \frac{1}{2\Delta}\left[\log_n \frac{\alpha - \frac{v_2}{L'_1 + \frac{C'}{B}}}{\alpha - \frac{Bv_1}{C'}} - \log_n \frac{\beta - \frac{v_2}{L'_1 + \frac{C'}{B}}}{\beta - \frac{Bv_1}{C'}}\right] \quad \ldots\ldots\ldots \quad (25)$$

In the case in which v_2 cancels out (the train stops) :

$$t'_1 = \frac{1}{2\Delta}\left[\log_n \frac{\alpha}{\alpha - \frac{Bv_1}{C'}} - \log_n \frac{\beta}{\beta - \frac{Bv_1}{C'}}\right] \quad \ldots\ldots\ldots\ldots \quad (26)$$

2) **If** $\frac{A^2}{4} - B < 0$,

$$\int_{s_1}^{s_2} \frac{ds}{s^2 + As + B} = -\frac{1}{\Theta} \text{ arc tg } \frac{\Theta\,(s_1 - s_2)}{\Theta^2 + \left(s_1 + \frac{A}{2}\right)\left(s_2 + \frac{A}{2}\right)}$$

whence :

$$T_1 = -\int_{s_1}^{s_2} \frac{ds}{s^2 + As + B} = +\frac{1}{\Theta} \text{ arc tg } \frac{\Theta\,(s_1 - s_2)}{\Theta^2 + \left(s_1 + \frac{A}{2}\right)\left(s_2 + \frac{A}{2}\right)}$$

If the section considered does not overlap the two periods :

$$T_1 = \frac{1}{\Theta} \text{ arc tg } \frac{\Theta\left(\frac{Bv_1}{C} - \frac{v_2}{L_1 + \frac{C}{B}}\right)}{\Theta^2 + \left(\frac{Bv_1}{C} + \frac{A}{2}\right)\left(\frac{v_2}{L_1 + \frac{C}{B}} + \frac{A}{2}\right)} \quad \ldots\ldots\ldots\ldots \quad (27)$$

In the case of v_2 cancelling out (the train stops) :

$$t_1 = \frac{1}{\Theta} \text{arc tg} \frac{\Theta \frac{Bv_1}{C}}{\Theta^2 + \left(\frac{Bv_1}{C} + \frac{A}{2}\right)\frac{A}{2}} \quad \ldots \ldots \ldots \ldots \ldots \ldots \quad (28)$$

If the section overlaps the two periods :

$$T'_1 = \frac{1}{\Theta} \text{ arc tg } \frac{\Theta \left(\frac{Bv_1}{C'} - \frac{v_2}{L'_1 + \frac{C'}{B}}\right)}{\Theta^2 + \left(\frac{Bv_1}{C'} + \frac{A}{2}\right)\left(\frac{v_2}{L'_1 + \frac{C'}{B}} + \frac{A}{2}\right)} \quad \ldots \ldots \ldots \quad (29)$$

In the case of v_2 cancelling out (the train stops) :

$$t'_1 = \frac{1}{\Theta} \text{ arc tg } \frac{\Theta \frac{Bv_1}{C'}}{\Theta^2 + \left(\frac{Bv_1}{C'} + \frac{A}{2}\right)\frac{A}{2}} \quad \ldots \ldots \ldots \ldots \ldots \quad (30)$$

3) **If $\frac{A^2}{4} - B = 0$.**

$$\int_{s_1}^{s_2} \frac{ds}{s^2 + As + B} = \frac{1}{s_1 + \frac{A}{2}} - \frac{1}{s_2 + \frac{A}{2}}$$

whence :

$$T_1 = -\int_{s_1}^{s_2} \frac{ds}{s^2 + As + B} = \frac{1}{s_2 + \frac{A}{2}} - \frac{1}{s_1 + \frac{A}{2}}$$

If the section considered does not overlap the two periods :

$$T_1 = \frac{1}{\dfrac{v_2}{L_1 + \dfrac{C}{B}} + \dfrac{A}{2}} - \frac{1}{\dfrac{Bv_1}{C} + \dfrac{A}{2}} \qquad (31)$$

In the case in which v_2 cancels out (the train stops) :

$$t_1 = \frac{1}{\dfrac{A}{2}} - \frac{1}{\dfrac{Bv_1}{C} + \dfrac{A}{2}} = \frac{2}{A} - \frac{1}{\dfrac{Bv_1}{C} + \dfrac{A}{2}} \qquad (32)$$

If the section overlaps the two periods :

$$T'_1 = \frac{1}{\dfrac{v_2}{L'_1 + \dfrac{C'}{B}} + \dfrac{A}{2}} - \frac{1}{\dfrac{Bv_1}{C'} + \dfrac{A}{2}} \qquad (33)$$

In the case of v_2 cancelling out (the train stops) :

$$t'_1 = \frac{2}{A} - \frac{1}{\dfrac{Bv_1}{C'} + \dfrac{A}{2}} \qquad (34)$$

N. B. — It must be remembered that in the equations 17, 18, 19, 20, 21, 22 and 25, 26, 29, 30, 33 and 34 above, the speed v_1 represents the speed v_B which is that of the end of the period of recharging the brake cylinders.

Second hypothesis.

The wheels of the various braked vehicles in the rake (as well as the wheels of the locomotives hauling the rake) have picked up and skid from the start of the period considered.

Let us take :

1) P_0 tons = the weight of the braked vehicles (wagons and locomotives) that is to say the weight of the part of the train the wheels of which are locked.

2) $(P - P_0)$ tons = the weight of all the non-braked wagons, P tons being the total weight of the train.

3) M = the total mass of the train, taking into account that the mass corresponding to the unbraked weight $(P - P_0)$ tons should be affected by the coefficient of majoration

$$= \frac{1000\ P_0}{g} + \frac{1000\ (P - P_0)\ \eta}{g}$$

$$= \frac{1000\ [P_0 + (P - P_0)\ \eta]}{g}$$

4) $f' = a' = b'v =$ the coefficient of sliding friction of the tyres on the rails allowed between the speed limits of $v_1 = v_B$ and $v_2 = 0$.

5) r_0 kilogrammes per ton = the specific rolling resistance *at low speed* of the rake (the resistance of the atmosphere being negligible here).

The differential equation of the movement can be written :

$$M \frac{dv}{dt} = - \{1000 f' P_0 + (P - P_0) r_0 + i P\}$$

$$= - \{1000 (a' - b'v) P_0 + (P - P_0) r_0 + K l + K'\}$$

$$= - \{-1000 b' P_0 v + K l + 1000 a' P_0 + (P - P_0) r_0 + K'\}$$

or, noting that $\frac{dv}{dt} = \frac{v\,dv}{dl}$:

$$M v \frac{dv}{dl} = - \{- 1000 b' P_0 v + K l + 1000 a' P_0 + (P - P_0) r_0 + K'\}$$

whence :

$$v \frac{dv}{dl} = - \left\{ - \frac{1000 b' P_0 v}{M} + \frac{K l}{M} + \frac{1000 a' P_0 + (P - P_0) r_0 + K'}{M} \right\}$$

Finally, taking :

$$A = - \frac{1000 b' P_0}{M} \quad \ldots\ldots\ldots (35)$$

$$B = \frac{K}{M} \quad \ldots\ldots\ldots\ldots (36)$$

and :

$$C = \frac{1000 a' P_0 + (P - P_0) r_0 + K'}{M} \quad (37)$$

if the section does not overlap the two periods,

or :

$$C' = \frac{1000 a' P_0 + (P - P_0) r_0 + K l + K'}{M} \ldots (38)$$

if the section overlaps the two periods, we find according to the case :

$$v \frac{dv}{dl} = - \left\{ A v + B l + C \right\} \ldots \text{(VII)}$$

or :

$$v \frac{dv}{dl'} = - \left\{ A v + B l' + C' \right\} \ldots \text{(VIII)}$$

differential equations of the same form as IV and VI, so that the relations 11 to 34 can still be applied provided the parameters A, B and C or C′ are given the values 35, 36 and 37 or 38 indicated above.

Note as regards equations 11, 13, 15, 17, 19, 21.

It is rather troublesome to get v_2 from these equations. It is consequently preferable to find v_2 as a function of v_1, to develop the integral of the differential equation of the form :

$$v \frac{dv}{dl} = - \left\{ Av + B\,l + C \right\}$$

by the Mac-Laurin theorem :

$$v = v_0 + F'(o)l + F''(o) \frac{l^2}{2} + F'''(o) \frac{l^3}{6} + \ldots\ldots$$

We find readily :

$$F'(l) = \frac{dv}{dl} = - \left\{ A + \frac{Bl}{v} + \frac{C}{v} \right\}$$

$$\text{whence } F'(o) = \left(\frac{dv}{dl} \right)_{\substack{l = 0 \\ v = v_0}} = - \left\{ A + \frac{C}{v_0} \right\}$$

$$\text{and } F''(l) = \frac{d^2v}{dl^2} = - \left\{ + \frac{B}{v} - B \frac{l}{v^2} \frac{dv}{dl} - C \frac{1}{v^2} \frac{dv}{dl} \right\}$$

$$= - \left\{ \frac{B}{v} - \left(\frac{Bl}{v^2} + \frac{C}{v^2} \right) \frac{dv}{dl} \right\}$$

$$= - \left\{ \frac{B}{v} - \frac{1}{v^2} (Bl + C) \frac{dv}{dl} \right\}$$

$$\text{whence } F''(o) = \left(\frac{d^2v}{dl^2} \right)_{\substack{l = 0 \\ v = v_0}} = - \left\{ \frac{B}{v_0} - \frac{C}{{v_0}^2} F'(o) \right\}$$

Nevertheless, the calculation of the derivatives of a higher order is again most laborious, and it is more convenient to keep to the derivatives $F'(0)$ and $F''(0)$, if need be by dividing the « section » into small enough sections so that the relation :

$$v_2 = v_1 + F'(0)l + F''(0) \frac{l^2}{2}$$

is acceptable.

N. B. — It should be pointed out that if during the whole recharging period the train moved over part of the line with a constant gradient, the speed v_1 and the distance run L_1, instead of being calculated as suggested in the first part of this investigation (*Bulletins* March and April 1948) can be deduced also from the differential equation III.

In fact we have seen that in the case considered, $K = 0$ and $D = D'$ so that the equation III is simplified and from calculated results becomes :

$$\frac{dv}{dt} = -\left\{\alpha\,(T - t)^n + [\beta\,(T - t)^n + \gamma]v + \Delta\right\}$$

with :

$$\alpha = -\frac{aQ}{M\,T^n},\ \beta = \frac{bQ}{M\,T^n},\ \gamma = \frac{kP' + k' - bQ}{M},\ \Delta = \frac{aQ + r_0P' + R_0 - i_0P}{M}$$

or :

$$\frac{dv}{dt} + [\beta\,(T - t)^n + \gamma]\,v = -\alpha\,(T - t)^n - \Delta$$

equation of the form :

$$\frac{dy}{dx} + Py = Q$$

in which P and Q are functions of x only and of which the integral is :

$$y = e^{-\int P\,dx}\left\{\int e^{\int P\,dx} Q\,dx + C^{ste}\right\}$$

(To be continued.)

INTERNATIONAL RAILWAY CONGRESS ASSOCIATION

15th. SESSION (ROME, 1950).

QUESTION XII.

What must the importance and the prevailing conditions of traffic be, in order that from the economic point of view :

a) the construction of a railway line;

b) the keeping operating an existing railway line;

should be useful?

REPORT

(Great Britain, North Ireland, Dominions, Protectorates and Colonies, America (North and South), China, Burma, Costa Rica, Egypt, India, Malayan States, Pakistan, Iraq, Iran),

by Sven Boye, cand. act.,

Divisional Officer, Norwegian State Railways.

PART I.

In working out this report, the following method has been used :

A questionnaire was to be replied to by all the member administrations. It contained 30 questions and was set up in collaboration with M. le Dr. Prof. Nicola Laloni, Chef du Service Commercial et du Trafic de la Direction Générale des Chemins de fer de l'Etat Italien.

The questionnaire in English was sent to 26 railway administrations, and answers were to be given within November 1st, 1949, but up to December 15th I have received answers from 4 railway administrations, and 5 administrations have answered that they were not able to give the particulars asked for. The other 17 administrations have not given any answers at all. Any replies which come to hand later, will be published as a supplement to this report.

The replies received came from the following railway administrations :

The Pennsylvania Railroad Company, U. S. A.

British Railways.

New Zealand Government Railways.

Ceylon Government Railway.

I. KEEPING EXISTING LINES IN OPERATION.

QUESTION 1.

Taking into account capital repayment, does your operating budget show a deficit for the last two years, as well as for the five years prior to 1939?

ANSWERS.

THE PENNSYLVANIA RAILROAD.

Both in 1947 and 1948 the Pennsylvania Railroad showed a net income. For the

five years 1934 to 1938, inclusive, this railroad produced a net income in each of the years in question.

The net income in the combined years 1947 and 1948 was not equal to the annual repayments required to liquidate the equipment trusts and it was necessary to utilize some of the profits accumulated in prior years for this purpose.

BRITISH RAILWAYS.

1948 (post year of Railway Executive operations) showed a deficit, and a further deficit is accruing for 1949.

NEW ZEALAND GOVERNMENT RAILWAYS.

Railway operating results after taking into account depreciation on assets, have shown a deficit for the last two years. For the five years prior to 1939, there was a net operating revenue sufficient to give a small return on the capital invested.

CEYLON GOVERNMENT RAILWAYS.

The operating budget or working expenses showed a deficit for the last two years (1946/47 and 1947/48) even without taking into account capital repayments. The operating budget for the 5 years prior to 1939 also showed similar deficits.

QUESTION 2.

Who met the operating deficit? What amount is carried by the State? What rating policy does the State impose on you?

ANSWERS.

THE PENNSYLVANIA RAILROAD.

In the United States, railroad operating deficits are normally met out of prior accumulated surpluses. If these are inadequate an attempt is generally made to float a bond issue or to obtain cash through the issuance of other property liens. Failing in this the property becomes bankrupt.

The State does not bear any of the cost of railroad operation. Government, both federal and State, exercices control over the rates, charged by railroad for all services rendered to the public. As a matter of practice rates continue until an application for a change therein is filed with the Interstate Commerce Commission (federal regulatory body) or with one or more of the public utility commissions (State regulatory body). These regulatory bodies hold hearings at which testimony is presented by the railroads and by such shipping or traveling people who desire to protest the proposed rate changes. Following these hearings, regulatory bodies approve or disapprove, in whole or in part, the rate changes requested by the railroads.

BRITISH RAILWAYS.

Clause 3 of the Transport Act 1947 provides that all the business carried on by the British Transport Commission (railway, docks, inland waterways, hotels and road services) are to be conducted as one undertaking and, subject to the provisions of the Act, the Commission are to levy such fares, rates, tolls, dues and other charges as to ensure that the revenue of the Commission is not less than sufficient for making provisions for the meeting of charges properly chargeable to revenue, taking one year with another.

NEW ZEALAND GOVERNMENT RAILWAYS.

All deficits are met in full by the State.

CEYLON GOVERNMENT RAILWAY.

As the Ceylon Government Railway is State owned, the State had to meet the entire deficit.

QUESTION 3.

Do you collect statistical data to determine the amount of traffic on each of your lines? What methods do you follow in the case of passenger traffic and goods traffic? How are your lines distributed amongst the various categories of traffic density adopted by you?

ANSWERS.

THE PENNSYLVANIA RAILROAD.

Statistical data is collected to determine the amount of traffic on various geographical portions of the Pennsylvania Railroad. The volume of traffic for statistical purposes is measured by :

1. Number of cars loaded.
2. Number of loaded cars dispatched.
3. Agents' revenue.
4. Dollar value of tickets sold.
5. Count of passengers at selected points.
6. Comptroller's report of actual revenues received.

Generally speaking these records are assembled to reflect the volume of traffic on each of the three Regions. They are also used to measure the traffic handled by each of the 29 Divisions. Territorially Pennsylvania Railroad seldom go below the division level except for special research involving possible abandonment of lines of tracks or other facilities.

BRITISH RAILWAYS.

Statistical data is collated regionally. The density of traffic on particular sections of line is kept under constant review by District Officers and additional statistical data collated as circumstances may require — for example, the counting of passengers in trains.

NEW ZEALAND GOVERNMENT RAILWAYS.

The following statistics are compiled for each train :

Gross Ton Miles.

Net Ton Miles.

Train Miles.

Train Hours.

Engine Miles.

Engine Hours.

With the exception of engine miles and engine hours the statistics are collated in suitable geographical sections of line, thus the density of traffic is readily available.

There is no formal systems of classification of lines according to traffic density.

CEYLON GOVERNMENT RAILWAY.

The reply is in the negative.

QUESTION 4.

Do you also collect statistical data in order to ascertain fluctuations in the traffic at different times of the year, on different days of the week, etc.? Do your statistics enable you to establish the degree of concentration of the traffic on the different lines, taking periodical fluctuations into account?

ANSWERS.

THE PENNSYLVANIA RAILROAD.

The principal purpose for collecting traffic volume data is to ascertain the fluctuations from week to week and even from day to day so as to relate the budgeted expenses to actual volume of traffic which is the first control point, making sure that the expenses will not exceed the operating revenues.

The statistics enable the company's officers to measure the concentration of traffic on the various Divisions but comparatively little use is made of the traffic statistics in so far as relative volumes by districts are concerned.

BRITISH RAILWAYS.

See answer to Question 3.

NEW ZEALAND GOVERNMENT RAILWAYS.

Each financial year ending on 31st March is divided into thirteen four-weekly periods. Gross and net ton mileage of trains, train miles and train hours are collected daily and summarized into weekly and four-weekly periods.

The statistics compiled are sufficiently detailed to enable the degree of concentration of traffic on the different lines to be established, taking into account seasonal or periodical fluctuations.

CEYLON GOVERNMENT RAILWAY.

The reply is in the negative.

QUESTION 5.

Do you set out separately the costs and receipts for each of your lines, in such a way as to establish partial budgets for each line?

ANSWERS.

THE PENNSYLVANIA RAILROAD.

Revenues and costs for each Region and each Division are ascertained for budgetary purposes.

BRITISH RAILWAYS.

No.

NEW ZEALAND GOVERNMENT RAILWAYS.

No separate costs and receipts are compiled for each line.

CEYLON GOVERNMENT RAILWAYS.

The reply is in the negative.

QUESTION 6.

Have the above mentioned statistical data enabled you to determine the class of lines the amount of traffic on which has an adverse effect on the financial stability of your railway system as a whole?

ANSWERS.

THE PENNSYLVANIA RAILROAD.

The aforementioned statistical data very definitely permits the railroad to identify the losing areas and points to reductions of expenses, facilities, etc., which may be necessary to bring the operating costs in line with the revenues in a given area.

BRITISH RAILWAYS.

This is dealt with on the basis indicated in answer to Question No. 3.

NEW ZEALAND GOVERNMENT RAILWAYS.

Not applicable.

CEYLON GOVERNMENT RAILWAY.

The reply is in the negative.

QUESTION 7.

Amongst the lines showing a deficit, what is the approximate percentage of lines which it is necessary to keep in operation :

1. *For technical reasons (exceptional traffic on the main lines, interruptions in the normal routing, etc.);*

2. *For economic reasons special to the operating company;*

3. *For political, social, etc., reasons.*

ANSWERS.

THE PENNSYLVANIA RAILROAD.

Intrinsically unprofitable lines are kept in service generally for two reasons, viz., the insistence of State regulatory bodies and the feeder value of such branch lines to the revenues of the profitable main lines. The Pennsylvania Railroad does not make a practice of retaining unprofitable lines for use as detour routes account interruptions on the lines normally used by freight and passenger trains.

BRITISH RAILWAYS.

The main governing factor for keeping any deficit line in operation is its contributory value to the undertaking as a whole.

NEW ZEALAND GOVERNMENT RAILWAYS.

Not applicable.

CEYLON GOVERMENT RAILWAY.

The reply is in the negative.

QUESTION 8.

Are you of the opinion that a more adaptable rating policy or a different form of operation and organization of the lines showing a deficit would

improve their present financial situation? Do you think it might be advantageous to suppress one or other service?

ANSWERS.

THE PENNSYLVANIA RAILROAD.

Freight and passenger rates are too complex and involved in their over-all industrial and competitive relationships to permit of any adjustment on unprofitable lines. The American rate structure is simply not built that way.

The management of the Pennsylvania Railroad frequently reviews the organization and the operating methods of each portion of the system, Special attention is directed to those branches or lines where the operation produces a deficit.

BRITISH RAILWAYS.

Cases arise where different methods of operation and/or organization improve the financial results; rates variations are not adopted.

NEW ZEALAND GOVERNMENT RAILWAYS.

Not applicable.

CEYLON GOVERNMENT RAILWAY.

Do not arise.

QUESTION 9.

Do you consider that lines at present operated by different companies or administrations could with advantage be regrouped, reorganized, divided up, etc.?

ANSWERS.

THE PENNSYLVANIA RAILROAD.

There are many locations where, under normal conditions of traffic, railroad lines and facilities could be consolidated with resultant elimination of some of these facilities and in many instances effecting operating economies. During the depression of 1930-1934 a large number of such consolidations were put in effect. Subsequent events demonstrated that it was fortunate that such consolidations were strictly limited. During the war every railroad facility was given the most intensive utilization and had the general railroad structure been constricted to the fullest possible extent under normal operating conditions, there would have resulted a very great inadequacy of roadway and supporting facilities to handle the enormous volume of freight and passenger business that was thrust upon the railroads during the recent war.

BRITISH RAILWAYS.

Apart from the London local urban lines and a few other minor exceptions all lines in Great Britain form one entity under the management of the Railway Executive : for convenience of administration, the lines are grouped into regions, but adjustment of boundaries between regions only is contemplated.

NEW ZEALAND GOVERNMENT RAILWAYS.

Not applicable.

CEYLON GOVERNMENT RAILWAY.

Do not arise.

QUESTION 10.

What is the policy of the State as regards protecting the railway against road competition? (Please give the measures adopted by the State in order to prevent the railways losing their traffic and the progressive depreciation of the capital invested in them.)

ANSWERS.

THE PENNSYLVANIA RAILROAD.

Government, both federal and State, takes no action to protect railroads against highway or other competition. On the contrary, government subsidizes other forms of transportation, such as highways, airways and waterways, through the utilization of federal or State funds for the construction or maintenance facilities used by these competing

forms of transportation. In the United States the railroads are privately owned. Government's interest in the railroads is one of great dependence upon them during periods of national emergency and complete disregard of their welfare in normal times.

BRITISH RAILWAYS.

The policy of the State regarding transport is contained in the Transport Act 1947, and certain sections of the Road and Rail Traffic Act 1930, and the Road and Rail Traffic Act 1933.

Briefly, the Transport Act provides for the acquisition by the British Transport Commission (acting under Treasury guarantee) of the British Railways. The British Transport Commission (assisted by « Railway » and other Executives) is responsible for securing the provision of an efficient, adequate, economical and properly integrated system of public inland transport and port facilities within Great Britain for passengers and goods with due regard to safety of operation. The Act requires the Commission to acquire road haulage undertakings, on payment of compensation, whose business is considered by the Commission to consist to a predominant extent of ordinary long distance carriage for hire or reward.

The Act also provides that from an appointed day (February 1st, 1950) goods must not be carried for hire or reward more than 25 miles from a vehicle's operating centre (except in the case of vehicles conveying liquids, in bulk, felled timber etc.), without a permit granted by the Commission.

The Act, however, does not empower the Commission to interfere in any way with traders who wish to use their own vehicles for the conveyance of their own goods.

So far as passenger road transport is concerned, the Act empowers the Commission to acquire passenger road transport undertakings as part of a scheme for securing or facilitating the promotion of the co-ordination of passenger transport facilities in an area, whether by road or rail.

NEW ZEALAND GOVERNMENT RAILWAYS.

The present policy of the State regarding the protection of the railway against road competition is briefly as follows :

Goods traffic :

In general terms, the policy is that for distances over 30 miles goods go by rail and for distance of 30 miles and under they may go by road. However, a considerable volume of long distance traffic is conveyed by road owing to :

a) poor enforcement of the law;

b) the power held by Road Licensing Authorities to grant route licences for distances over 30 miles.

Passenger traffic :

All road services are licensed and the policy has generally been one operator to one route, each operator having therefore a virtual monopoly on his route. 51 % of the mileage of all route licenses is at present held by the Railways Department and 49 % by private operators.

The existing state of affairs is being upset by :

a) the tendency to grant licenses for long distance luxury services;

b) the use of contract licenses for long distance travel.

The position regarding long distance passenger road services is at present engaging attention of the recently appointed Transport Co-ordination Council.

CEYLON GOVERNMENT RAILWAY.

The Railway is not protected against road competition and continue rigorously to adhere to a statutory goods classification and rates schedule, while road hauliers have the advantage of quoting separate rates for different traders and diverting traffic from the Railway. Proposals for the determination of the sphere of road and rail have been made, but State action is being awaited.

QUESTION 11.

What are the financial effects of road competition on the railway?

ANSWERS.

THE PENNSYLVANIA RAILROAD.

Financial effects of highway competition on the railroads are severely felt. One of the most damaging effects is the fact that the railroads must gear themselves to handle virtually the entire freight and passenger business of the nation during periods of war as the trucks are largely eliminated through the shortage of rubber and gasoline.

In peace times the subsidized highway competition is able to underquote railroad rates, select the most lucrative commodities for transportation, and thus deprive the railroads of what should normally be some of their most lucrative traffic. Prior to the war, trucks were handling about 10 % of the country's intercity traffic. During the war this dropped to almost 3 %, but in 1948 it has risen to 13 %. The ability of the trucks to take business away from the railroad, except for exceedingly short haul movements, is due entirely to government's policy of subsidizing the highways.

BRITISH RAILWAYS.

During the last 20/30 years road competition has resulted in the diversion from the railways of a substantial tonnage of the more highly rated merchandise, with consequent serious effect upon railway revenues.

NEW ZEALAND GOVERNMENT RAILWAYS.

Road competition with the rail exists to a marked degree on certain routes but there is no data available showing the extent to which these operations affect the finances of the railway.

CEYLON GOVERNMENT RAILWAY.

There has been an allround drop in the revenue as a result of the cessation of wartime traffic.

QUESTION 12.

What is the present (and the pre-war) average cost per passenger/km and ton/km carried by the railway, including sinking fund charges? What method do you follow as regards this sinking fund?

ANSWERS.

THE PENNSYLVANIA RAILROAD.

In 1948 the Pennsylvania's average cost per ton mile was 1.045 cents. This is based on the formula division between freight and passenger costs prescribed by the Interstate Commerce Commission. In the same year the average revenue per ton mile was 1.299 cents. The last pre-war year, 1940, showed an average ton mile cost of 0.608 cents and a revenue of 0.914 cents per ton mile. It is impossible to provide corresponding figures for the passenger service.

BRITISH RAILWAYS.

These figures are not ascertained as a general statistic.

NEW ZEALAND GOVERNMENT RAILWAYS.

No separate passenger or goods costs are compiled. No sinking fund is operated. The amount set aside for depreciation is used to replace the depreciating assets.

CEYLON GOVERNMENT RAILWAY.

Statistics showing the costs separately for passengers and goods traffic by rail and road transport are not maintained.

QUESTION 13.

What are (and what were pre-war) the costs of road transport taking into account capital depreciation?

ANSWERS.

THE PENNSYLVANIA RAILROAD.

There are no accurate statistics covering the cost of transportation by highway. The highways are maintained by the public,

the direct financing being through the federal government, the State government or the local government. In the case of the larger trucking companies which are required to make certain financial statements the Pennsylvania Railroad have some idea of their operating costs. Recent statistics showed the distribution of the revenue dollar for trucking companies to be as follows :

	Cents
Maintenance of equipment .	16.2
Maintenance of way . . .	0.0
Transportation	55.6
Traffic	2.2
General and fixed charges	13.3
Taxes	5.3
Rentals	2.3
Net revenue	5.1
	100.0

According to the American Trucking Association the cost of repairs and servicing of motor trucks amounted to 4.2 ct. per truck-mile, fuel 2.3 ct., equipment maintenance and garage expense 6.7 ct., terminal expense per ton of freight $ 3.22, taxes and licences per vehicle $ 906. The average lading weights 8.62 tons, average haul 195 miles, average tons per vehicle per year 2 324. All data applies to Class I carriers only.

BRITISH RAILWAYS.

No answer.

NEW ZEALAND GOVERNMENT RAILWAYS.

The cost of operating road services, per vehicle mile, in 1939 was 12.27 pence as compared with 22.11 pence in 1949.

CEYLON GOVERNMENT RAILWAY.

See answer to Question No. 12.

QUESTION 14.

When the road costs are the most favourable, have you considered suppressing railway services?

ANSWERS.

THE PENNSYLVANIA RAILROAD.

The Pennsylvania Railroad Company has assumed that the phrase « suppressing railway services » means decreasing the rates charged the public.

In order to compete with the highways the railroads have, particularly on a local basis effected rate reductions. Generally speaking this does not apply to short distant movements as it is almost impossible for the railroad to compete with the trucks at short distances. To reduce such rail rates would very frequently result in handling the traffic at a distinct loss to the company.

BRITISH RAILWAYS.

Each case is judged on merits.

NEW ZEALAND GOVERNMENT RAILWAYS.

With a view to improving the passenger services, the passenger cars on mixed trains have where possible been withdrawn and motor vehicles placed on the road to cater for the passengers. This has permitted of the more economical use of goods trains. In order to secure the better use of railway wagons, road motor lorries are operated for handling of small lots of goods between stations where full wagon loads are not offering.

CEYLON GOVERNMENT RAILWAY.

Does not arise in view of reply to 12 and 13.

QUESTION 15.

What advantage would it be from the cost point of view for the railway to give up all the lines showing a deficit? Do you consider that the railways might be able to meet the road competition in this way without any other protective measures?

ANSWERS.

THE PENNSYLVANIA RAILROAD.

If the railroads were able to abandon all unprofitable lines they would of course

show a somewhat more favourable net income than is otherwise the case. However, this is not a major factor in the railroad's financial results. The major factors are the rates which the railroads are permitted to charge for freight and passenger movements, the wage levels they are required to pay their employes and the ability or disability of competitive agencies of transportation to take away business heretofore handled by the railroads. The abandonment of unprofitable branches does not and could not materially change these major economic factors.

BRITISH RAILWAYS.

The question as to whether any particular section of line should be closed has to be decided on the particular circumstances of the section concerned. Regard has to be had to the potentiality of the traffic; its contributory value to the undertaking as a whole; the ownership of alternative services which would be required to deal with the traffic, i. e. whether owned by B. T. C. or not; the cost of providing alternative services for coal and other traffic now passing by rail; and the extent of the economies to be derived from closing the line.

NEW ZEALAND GOVERNMENT RAILWAYS.

No separate costs are compiled for separate sections of lines and no deficit can be allocated specifically to any line. Branch lines were constructed for the purpose of developing the country and are required as subsidiary to the main lines.

CEYLON GOVERNMENT RAILWAY.

Does not arise in view of the reply to 12 and 13.

QUESTION 16.

What consequences would the possible suppression of the deficit showing lines have on the main line traffic? Up to what point would these consequences justify maintaining part of the deficit showing lines in service?

ANSWERS.

THE PENNSYLVANIA RAILROAD.

Elimination of unprofitable lines would of course remove a certain amount of traffic from the profitable main lines. However, with the use of buses and trucks as feeders this loss is somewhat ameliorated.

BRITISH RAILWAYS.

See answer to Question No. 15.

NEW ZEALAND GOVERNMENT RAILWAYS.

See answer to Question No. 15.

CEYLON GOVERNMENT RAILWAY.

Does not arise in view of reply to 12 and 13.

QUESTION 17.

In what way do you think it would be possible to divert to the main lines the traffic from deficit showing lines which it has been decided to abandon?

Should the railway itself operate these road services? If so : directly or by means of an affiliated company under its control?

ANSWERS.

THE PENNSYLVANIA RAILROAD.

This question is partly answered in the preceding reply. In some instances the railroad itself operates substituted services, viz. truck and bus. Most generally, however, these services are operated by independent companies although in many other cases they are affiliates or subsidiaries of the railroad company. Here again, this is not of vital importance as the relative volume of such traffic is very small compared with the railroad's total revenue.

BRISTISH RAILWAYS.

See answer to Question No. 15.

NEW ZEALAND GOVERNMENT RAILWAYS.

See answer to Question No. 15.

CEYLON GOVERNMENT RAILWAY.

Does not arise in view of reply to 12 and 13.

QUESTION 18.

Do you consider that the arguments generally brought to bear against closing down deficit showing railway lines could be refuted if the railways organised corresponding road services, covered by the same legal regime as railway services, and if they adopted the same rates and granted the same reductions?

ANSWERS.

THE PENNSYLVANIA RAILROAD.

No answer.

BRITISH RAILWAYS.

See answer to Question No. 15.

NEW ZEALAND GOVERNMENT RAILWAYS.

See answer to Question No. 15.

CEYLON GOVERNMENT RAILWAY.

Does not arise in view of reply to 12 and 13.

II. NEW LINES.

QUESTION 19.

Have any new railway lines been built in your country since 1944 (if so, please give the length, operating regime, purpose, etc.)?

ANSWERS.

PENNSYLVANIA RAILROAD.

No important new railway lines have been built in this country since 1944. The only new constructions have been relatively short and unimportant branches to reach new coal lands, new industrial plants, etc., and occasional so-called « cut-offs », which are realignments of existing railroads in order to reduce length of the line, curvature or the grading.

BRITISH RAILWAYS.

No new railway lines have been built since 1944, but certain tracks have been quadrupled and others electrified.

NEW ZEALAND GOVERNMENT RAILWAYS.

The following lines have been completed and taken over by the Working Railways Department since 1944 :

Date	*Section of Line*	*Length*		*Purpose*
		Miles	*Chains*	
15-12-45	Hundalee Kaikoura	23	30	To complete South Islands main trunk line. This section of line connected an isolated section in the north of the South Island with the remainder of the system.
7- 1-46	Waterloo-Naenae	1	36	Extension of Hutt Valley Railway to new housing areas and part of comprehensive scheme for Hutt Valley suburban area.
14- 4-47	Naenae-Taita	1	71	

CEYLON GOVERNMENT RAILWAY.

Reply is in the negative.

QUESTION 20.

Are any lines under construction or proposed? (Please give the length, operating regime, purpose, etc.).

ANSWERS.

THE PENNSYLVANIA RAILROAD.

The Pennsylvania Railroad does not contemplate the construction of any new lines other than minor branches or realignments.

BRITISH RAILWAYS.

No important lines.

NEW ZEALAND GOVERNMENT RAILWAYS.

The following line is under construction :

Line	*Approximate length*	*Purpose*
Putaruru to near Reparoa	18 1/4 miles	To serve a large area of exotic and native forest-line; will also handle inwards traffic for Waikato River hydro-electric works.

The following line is under survey, and construction is expected to commence in the near future :

Line	*Approximate length*	*Purpose*
Edgecumbe to Murupara	47 3/4 miles	To serve a large area of exotic forest. At Murupara it is intended to establish a State pulp and paper mill.

CEYLON GOVERNMENT RAILWAY.

Reply is in the negative.

QUESTION 21.

If the answers to question 19 and 20 have been in the affirmative, please state if the construction of these lines was decided upon for economic or other reasons.

ANSWERS.

THE PENNSYLVANIA RAILROAD.

The construction of such branch lines, realignments etc., are purely for economic reasons.

BRITISH RAILWAYS.

NEW ZEALAND GOVERNMENT RAILWAYS.

The lines mentioned above have been or are being constructed for economic reasons.

CEYLON GOVERNMENT RAILWAY.

Does not arise in view of reply to 19 and 20.

QUESTION 22.

Have considerations of general and national economy had a predominating influence, apart

from the expected returns of the undertaking? What motives of national economy led to the new lines being built? What financial returns are expected?

ANSWERS.

THE PENNSYLVANIA RAILROAD.

Except during periods of war considerations of general and national economy, have no influence on the construction of new lines of railroads.

BRITISH RAILWAYS.

The improvements mentioned in the answer to Question 19 were mainly effected for the purpose of providing better services in congested suburban traffic areas.

NEW ZEALAND GOVERNMENT RAILWAYS.

Considerations of the general and national economy have had much bearing on the construction of new lines in New Zealand. The expected returns have seldom been the predominating influence. The final decision regarding the construction of any new line rests with the government of the day.

Regarding the railways mentioned in the answer to Question 20 :

It is anticipated that traffic on both these lines will be very heavy and that revenue will be more than sufficient to meet the operating expenses as well as interest on capital (3 1/2 %).

Regarding the railways mentioned in the answer to Question 19 :

The Kaikoura-Hundalee section has been built from considerations of national economy.

CEYLON GOVERNMENT RAILWAY.

Does not arise in view of reply to 19 and 20.

QUESTION 23.

With the cost of railway and road traffic as they are at present time, in your opinion what volume of traffic is necessary if the construction of a new railway line is to be a paying proposition, taking into account interest on the capital invested?

ANSWERS.

THE PENNSYLVANIA RAILROAD.

It is impossible to lay down any formula in answer to this question. In this country new construction for a first-class railroad runs about $ 145 000 per track mile. Secondary tracks and siding are considerably cheaper. To determine whether a branch or siding is to be constructed, consideration must be given not only to the traffic immediately in sight but also to the long range volume of traffic which is a determinate in ascertaining whether or not the construction investment can be liquidated in a reasonable period of years.

BRITISH RAILWAYS.

This question and Question No. 24 are not generally applicable to Great Britain, where, apart from the need for a few more passenger routes in the London urban area the existing railway facilities are considered adequate for requirements of the community. Obviously in connection with the projection of any new line, the principal items to be considered would be the extent and nature of the traffic to be carried.

NEW ZEALAND GOVERNMENT RAILWAYS.

Each particular proposed line must be considered on its merits and the volume of prospective traffic should be such as will be sufficient to pay operating expenses, including depreciation, and give a reasonable return for interest on capital.

CEYLON GOVERNMENT RAILWAY.

Does not arise in view of reply to 19 and 20.

QUESTION 24.

What methods can be adopted to determine the probable traffic on a new railway line, supposing that sufficient statistical data are available concerning the economic situation of the district concerned? To which statistical data do you attach the greatest importance?

ANSWERS.

THE PENNSYLVANIA RAILROAD.

The Pennsylvania Railroad has presumed

that this question and Question No. 25 apply to the construction of new lines into new territory. This has not occurred for a great many years and generally speaking in this country it is confined to the development of areas having mineral resources. These are generally susceptible of fairly accurate traffic forecasts. However, the mere presence of a vast reserve of coal is not assurance that it will be mined as the cost of recovering this coal may be greater than the cost of recovering equal quality coal in some other district. Thus to accurately evaluate the economics of new railroad construction, the engineer must also evaluate the economic potential of the industries that such a line of railroad would serve.

BRITISH RAILWAYS.

See answer to Question No. 23.

NEW ZEALAND GOVERNMENT RAILWAYS.

The traffic potential of a proposed new railway is obtained as far as practicable from official sources, i. e., Department of Agriculture, Foresty Department etc. Other sources of information are local bodies, Chambers of Commerce and large firms or businesses operating within the area to be served.

CEYLON GOVERNMENT RAILWAY.

Does not arise in view of reply to 19 and 20.

QUESTION 25.

What characteristics of an important traffic, concentrated in given periods of the day, week or year, in your opinion would make it necessary to build a new railway line?

ANSWERS.

THE PENNSYLVANIA RAILROAD.

See answer to Question No. 24.

BRITISH RAILWAYS.

Principal items would be density and nature of traffic to be carried.

NEW ZEALAND GOVERNMENT RAILWAYS.

A new railway line would be justified where the volume of an important traffic was such that it could not be more economically transported by road. In considering any particular project, regard would be paid to :

a) Class of product.

b) Continuity of output.

c) The potential of the area to be served.

CEYLON GOVERNMENT RAILWAY.

Does not arise in view of reply to 19 and 20.

QUESTION 26.

Are you of the opinion that road transport has already reached such a stage of development that it can deal with transport in bulk?

ANSWERS.

THE PENNSYLVANIA RAILROAD.

Highway transportation has reached a stage of development that enables it to transport commodities in bulk. In this country powerful tractors are used to draw trailers in multiple so that without increasing the tons per square foot of pressure on the highway, the number of gross tons per unit has multiplied many times in the past two decades.

BRITISH RAILWAYS.

Road transport can convey « bulk » loads of many commodities, but a large number of goods vehicles would be required to carry a tonnage equal to one train load, and the question of the return road journeys has to be considered.

NEW ZEALAND GOVERNMENT RAILWAYS.

So far as New Zealand is concerned, road transport does not yet appear to have reached a stage where it can deal with the volume of bulk traffic handled by the railways. Road vehicles are probably capable of handling most types of traffic offering, but the roading system is not yet adequate. Most of the roads in this country are not constructed to a sufficiently high standard to enable them to bear the heavy

traffic conveyed by rail. The matter of road congestion has also to be taken into account.

CEYLON GOVERNMENT RAILWAY.

The road transport has not reached such a stage of development that it can deal with transport in bulk.

QUESTION 27.

Taking into account the possibilities now offered by other methods of transport, can it be affirmed that nowadays the construction of new railway lines is essential to the economic development of a district and backward countries, and investing capital in this way is the most economic solution from the national point of view?

ANSWERS.

THE PENNSYLVANIA RAILROAD.

Railway systems remain the backbone of transportation in America. Where new industries or new natural resources are to be developed adequate railroad transportation remains a prime essential to that development. Substitute forms of transportation are still inadequate.

BRITISH RAILWAYS.

Each case would require to be judged on merits.

NEW ZEALAND GOVERNMENT RAILWAYS.

It appears that in most circumstances the answer to this question is in the negative.

CEYLON GOVERNMENT RAILWAY.

The reply is in the affirmative.

QUESTION 28.

If so, what form of management should be set up? How should relations with the State be regulated : either as regards the financial needs of the new lines, or as regards subsidizing the future operation of these lines if necessary?

ANSWERS.

THE PENNSYLVANIA RAILROAD.

There is no need for the regulation of any form of transportation by the State generally or locally. At one time the railroads were virtually the only important commercial transporters of goods and persons. To prevent discrimination and monopoly, federal and State regulatory commissions were created. With the advent of the truck, the pipe line, the inland waterways and the airways, the monopoly aspects of railroads were abolished. With the maturing of such competitive agencies of transportation all possibility of genuine monopoly has dissolved and with it all genuine need of regulatory commissions. States should play no role in the transportation field. Should not subsidize any form of transportation. Should invest no capital in construction for transportation and should not attempt in any way to regulate transportation service. If left to their own devices competition among agencies of transportation will result in adequate and cheap transportation for the shipper and traveler. If any form or line of transportation cannot be made to pay its own way, it should go out of business and not be supported by State. This is incontestably true in America and must be true in other nations as well.

BRITISH RAILWAYS.

See answer to Question No. 27.

NEW ZEALAND GOVERNMENT RAILWAYS.

This question is not applicable to the conditions in New Zealand. All new lines are constructed by the State and are State owned and operated.

CEYLON GOVERNMENT RAILWAY.

New lines should be built and run by the State.

QUESTIONS LIMITED TO THOSE COUNTRIES WHICH SUFFERED WAR DAMAGE.

QUESTION 29.

At the end of the war, was an organic plan prepared for the reconstruction of the damaged railway lines? Were any committees, Councils, etc., set up with this object?

ANSWERS.

BRITISH RAILWAYS.

Plans were prepared in the normal course

by the technical departments of the main line railways for the restoration of war damage. The necessary work is being carried out by the railways under the direction of the Railway Executive as sufficient labour and materials become available.

***

The Pennsylvania Railroad, New Zealand Government Railways and Ceylon Government Railway did not suffer war damage.

QUESTION 30.

Did any differences of opinion arise concerning this reconstruction? In your opinion can it be stated that the decisive influence on the railway reconstruction policy is attributable to temporary considerations (public works policy, employment for the unemployed, etc.) or permanent ones (recognition of the social value of railway transport, insufficient evaluation of the possibilities of using road transport economically)?

ANSWER.

BRITISH RAILWAYS.

The main considerations governing the restoration of war damage to British Railways were permanent ones and work was not carried out merely as a public works policy for the purpose of providing work for the unemployed.

PART II.

SUMMARY.

It appears from answers that all the railway administrations concerned except the Pennsylvania Railroad had a deficit in the last two financial years.

The railways in Great Britain were nation alized in 1948 and have not given any information with regard to deficit or net income in the five financial years prior to 1939.

New Zealand Government Railways showed a net income in the five years prior to 1939.

Ceylon Government Railway showed a deficit in the last two years as well as in the five years prior to 1939.

The railways in New Zealand and Ceylon are State owned and all deficits are covered in full by the State. In Great Britain where the greater part of the system of transportation including the railways is owned and conducted by the British Transport Commission acting under Treasury guarantee, the State require that the Commission are to levy such fares, rates, etc., so as to ensure that the revenue of the B. T. C. as a whole is not less than sufficient for making provisions for the meeting of charges properly chargeable to revenue.

In U. S. A. where the railways are private owned, the State do not cover any of the costs of railway operation.

All the railway administrations concerned except Ceylon Government Railway collect statistics divisionally in order to ascertain the volume and fluctuation of traffic of each of their lines, but only Pennsylvania Railroad sets out separately the costs and receipts for each division of line in order to establish partial budgets.

None of the railway administrations concerned applies rate variations for certain sections of line in order to improve the financial results of the deficit showing lines. On the other hand they try to achieve this by adopting new methods of operation and organization.

In New Zealand they have suppressed certain services on special sections of lines. Thus, where possible, they have withdrawn the passenger cars from the mixed trains and replaced them by motor vehicles on the road to cater for the passengers.

The question of abandoning the deficit showing lines is in U. S. A. dealt with solely on the basis of which value the railway-line has to the railway company concerned. Considerations of national economy and social welfare have no influence on these decisions. However, a decision to close down operation on a specific line has to be sanctioned by federal and State regulatory bodies.

In Great Britain as mentioned above, the greater part of the system of transportation is by now in State ownership. Consequently the system of transportation is regarded as a whole, and decisions of abandoning a deficit showing railway line

are taken on the basis of which value the railway line concerned has to the British Transport Commission.

In New Zealand the decisions as to closing down operation on a line or not, are taken on the basis of which value the railway line concerned has to the country as a whole. Thus, special stress is laid upon considerations of national economy.

In U. S. A., according to the answer from the Pennsylvania Railroad, the State is subsidizing the road transport, the airways and the inland waterways, whereas the railways do not get any support from the State. However, the rates and fares are controlled by federal and State regulatory bodies. Thus the railways in U. S. A., according to the opinion of the Pennsylvania Railroad, are repressed in the competition with other means of transport.

In Great Britain, the State try to coordinate the whole system of transportation, partly by means of nationalization and partly by means of new legislation. Thus there is with certain exceptions laid down a limit of 25 miles from a vehicle's operating centre, within which vehicles are allowed to transport goods on the road.

In New Zealand they also try to bring competition between railways and road transport under control by laying down a limit for the sections where the goods transports have to go by road and where they have to go by railway. Passenger traffic by road vehicles is also subject to control by the State as all routes are licensed, and the policy has generally been to give license to one operator on one route. Each operator therefore has a certain monopoly on his route. As 51 % of the mileage of all route licenses at present are held by the Railway Department, the railways in New Zealand are relatively well protected against competition from road vehicles.

The general impression of the answers is that the railways are not able to compete with the road transport on short distances and that the road transport with its more free position in fixing the rates is able to divert the more highly rated goods from the railways.

On the question if it from a cost point of view would be useful to give up all deficit showing lines, and if the railways are able to meet the road competition in this way without any other protective measures, the Pennsylvania Railroad answers that there would be no difficulty in showing a more favourable net income by doing so. But they do not consider this as the main problem. They consider the rating policy that the regulatory bodies allow them to carry on, far more important.

According to the answer from the Pennsylvania Railroad, the building of new railway lines in U. S. A. has ceased for the time being. Construction of new railway lines into new territories has not occurred for a great many years. Only in territories where new industries or new mineral resources are to be exploited, the question of constructing new railway lines arises. New railway lines will only be constructed if they can be expected to give an ample return to the railway company. Considerations of national economy have no influence on the construction of railways in U. S. A. Even if U. S. A. must be regarded as the country in the world where the road transport has reached the highest stage of development, they still consider the railways as the « backbone » in the inland system of transportation.

In Great Britain they also regard the construction of new railway lines as ended. Thus, the problems of general railway policy in Great Britain as well as in U. S. A. are more attached to the existing railway lines.

In New Zealand they are still constructing new railways, but here considerations of public interest have a predominating influence on the decision of constructing a new railway line.

It appears from the answers that the traffic conditions are very different in the countries in question and even inside the various countries. Also the general economic policy of the governments in the various countries differs. These facts are probably the main reasons for the difference in the railway policy pursued by the various railway administrations.

[625 .143 .4]

INTERNATIONAL RAILWAY CONGRESS ASSOCIATION

15th. SESSION (ROME, 1950).

QUESTION II.

Rail-joints : improvements in fishplated joints. — Use of long welded rails : optimum length in relation to the safety and good condition of the permanent way. — Expansion gaps. — Determination of standard allowances.

REPORT

(Belgium and Colony, France and Colonies, Luxemburg, Netherlands and Colonies, Norway, Poland, Switzerland, Syria),

by O. LEDUC,

Ingénieur en chef au Service Technique des Installations fixes de la Société Nationale des Chemins de fer français.

This question consists of three parts :

First part : Rail joints — progress achieved as regards the fishplating.

Second part : Use of long welded rails — optimum length as regards safety and the good behaviour of the track.

Third part : Regulations governing the joint gap.

The principal idea around which these three parts gravitate is obviously the second, that dealing with long rails. The joint is in fact the weakest part of the track, to which railway engineers have long devoted their attention. In spite of the improvements that have been made (first part) the joint must always take into account the question of expansion (third part) and the greatest improvement that can be made to it is to decrease the number of joints required (second part) and even do away with them altogether.

Of the 48 administrations consulted, 20 replied to the questionnaire, but only 9 gave any positive information. These 9 were :

— Belgian National Railways (first, second and third parts).

— Danish State Railways (second and third parts).

— French National Railways (first, second and third parts).

— Morocco Railways (third part).

— Franco-Ethiopian Railway from Djibouti to Addis-Ababa (first, second and third parts).

— Algerian Railways (first, second and third parts).

— Netherlands Railways (first, second and third parts).

— Swiss Federal Railways (second and third parts).

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FIRST PART.

Rail Joints. — Progress made in the construction of the fishplates.

We do not think it would serve any useful purpose to go into the history of the joint, although very many different types have been used or tried out on all the railways since the beginning of the railways, as interesting as this might be, it would have no practical value.

Likewise, we have not considered it necessary to describe all the different types of joints still in use or being tried out on the permanent way, either because these joints have not given the hoped for results (for example the Dupuis, Odiot, Wolber joints in France), or because recent developments have completely altered the value of the types of joints in service (for example the systematic adoption of a new type of rail on the important lines, such as the 63 kg (138.89 lbs.) rail which has taken the place of the 46.9 kg (103.39 lbs.) rail in Holland).

The following report therefore only covers the equipment of the administrations consulted on the most up to date lines recently put into service on lines with heavy traffic.

The study of the different types of joints reported has been carried out in the following way corresponding to the order of the 26 questions asked :

1. Examination of the principal characteristics of the lines in question, type of rails, kind of sleepers, the way they are laid, especially the arrangement near joints (questions 1 to 4).

2. Descriptions of the different types of joints, kind of fishplate and extent of the fishplating (questions 5 to 8) :

— arrangement of the rails at the joint, drilling, tolerances as regards wear, burrs, support of the rails, expansion (questions 9 to 16);

— elastic bushes fillers or fishplates (question 16);

— bolts and devices to prevent unscrewing (questions 17 to 19);

— methods of manufacturing the fishplates and reception tests (question 20).

3. Maintenance of the joint (questions 21 to 25).

4. Insulated joints (question 26).

I. PRINCIPAL CHARACTERISTICS OF THE LINES CONCERNED.

Rails. — The 1st table hereafter sums up the information collected :

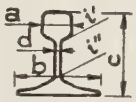
The Vignole rail is used exclusively. Its weight per lineal metre varies from 45.9 kg (101.19 lbs.) (Switzerland) to 63 kg (Holland).

It is generally laid on wood sleepers, with metal bearing or sole plates, whilst only the Danish State Railways lay it directly on the wood sleepers, their rails having very wide flanges (156 mm = 6.14 in.). The Swiss Federal Railways and the Belgian National Railways also use metal sleepers with the type of rails in question, not very often in Belgium, but frequently in Switzerland.

The arrangement of the sleepers near the joint is summed up in the following 2nd table.

Thus all the railways lay their sleepers closely together at joints, though none of them now make use of joints carried on a single sleeper.

The joint is always overhanging, even when it rests on two sleepers laid almost side by side : double metal sleepers (Switzerland and Belgium), two wood sleepers connected together by bolts with the edges touching (Switzerland and Holland) or not (Denmark, 50 mm [1.96 in.] stay between the sleepers), the amount of the overhang (distance between the ends of the rail

ADMINISTRATIONS	Cross-section V Vignole	Weight per lineal metre kg	 Dimensions (in mm) and cant of the fish-plating					
			a	*b*	*c*	*d*	*i'*	*i''*
Belgian National Railways. . .	V	50.000	72	140	151	15	1/3	1/3
Danish State Railways	V	60.080	70	156	172	16	1/3	1/3
French National Railways . . .	V	50.568	65	140	153	15.5	1/3	1/3
Algerian Railways	V	49.560	67.5	130.6	143.3	14.3	23/100	23/100
Netherlands Railways	V	63.100	76	156	176	16	1/3	1/3
Swiss Federal Railways	V	45.900	65	125	145	14	1/4	1/4

Note — As regards the Algerian Railways, it is the A. R. A. B. rail which is manufactured in the United States. This rail was used immediately after the war. Normaly, this railway uses the French National Railways rail, but it appeared of interest to mention the A. R. A. B. rail here in view of certain peculiarities of the fish-plating (see further on).

ADMINISTRATIONS	Kind of sleeper	Arrangement at joints (mm)			
Belgian National Railways. . . .	Wood	*a* = 284	*b* = 500	*c* = 560.5	*d* = *e* = 607
Danish State Railways	Wood	*a* = 310	*b* = 500	*c* = 581	*d* = *e* = 611
French National Railways	Wood	*a* = 294	*b* = 483	*c* = 570	*d* = *e* = 600
Algerian Railways	Wood	*a* = 535	*b* = 630	*c* = *d* = *e*	= 670
Netherlands Railways	Wood	*a* = 250	*b* = 593	*c* = *d* = *e*	= 610
Swiss Federal Railways	Wood	*a* = 216	*b* = 542	*c* = 575	= 610

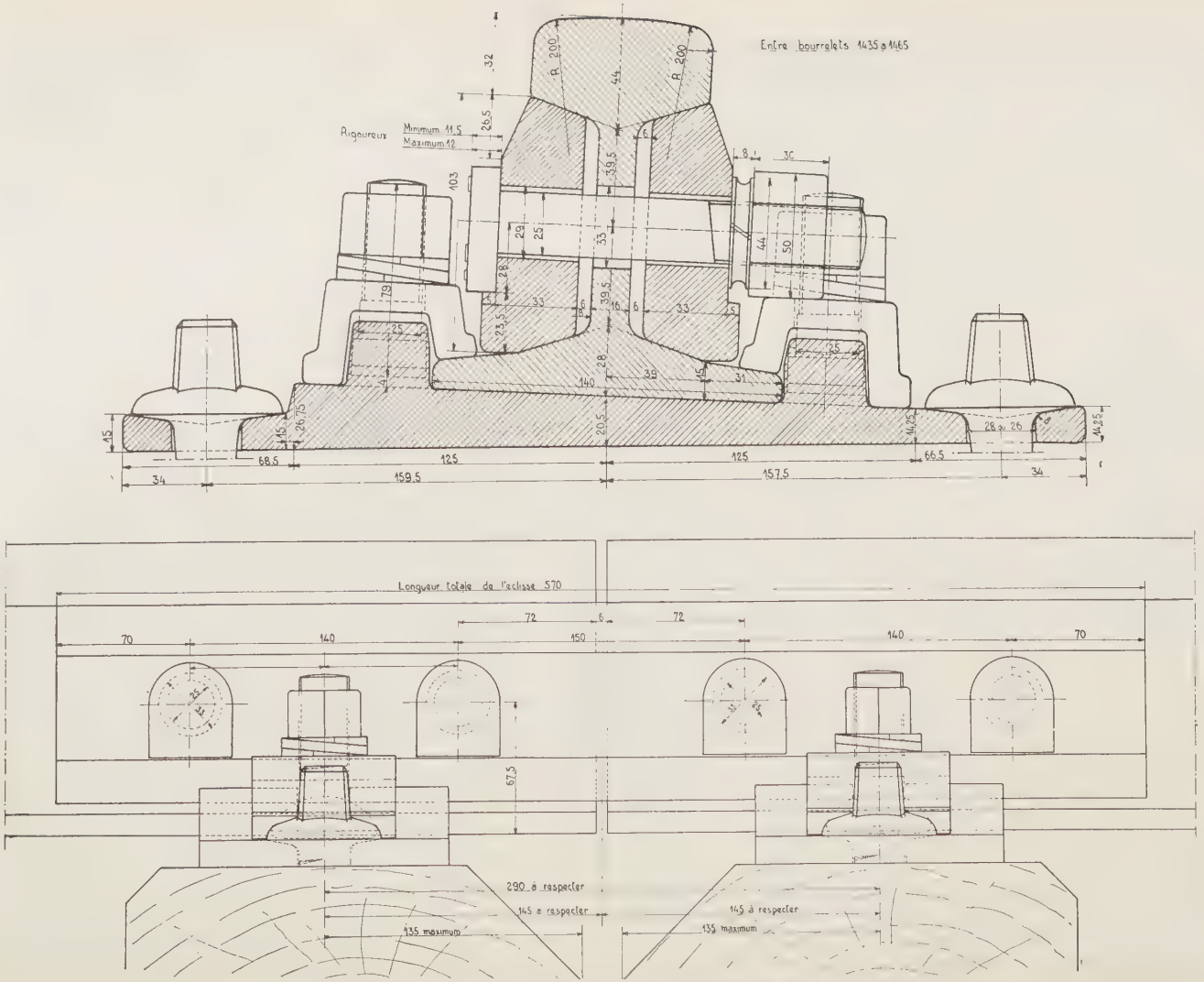


Fig. 1. — Belgian National Railways (S. N. C. B.) Fishplating.

Rigoureux minimum — Rigoureux maximum — Rigoureux minimum maximum — Entre bourrelets = Between flanges — Longueur totale de

supports each side of the joint) is at least 60 mm (2.36 in.) (Zwitzerland), more often 140 to 150 mm (5.51 to 5.90 in.) and sometines as much as 336 mm (14.01 in.) in Algeria.

The joints are usually in line. However the Netherlands Railways make use of staggered joints on curves of radius of less than 500 m (1640′ 5″) without explaining why, and the Algerian Railways report that with the 36 m (118′ 1 1/4″) long A. R. A. B. rails they have obtained the best results with staggered joints.

The same sleepers are used for joints as under the rest of the rail on most railways (2.5 to 2.7 m [8.20 to 8.85 ft.] long, 0.24 to 0.28 m [9.44 to 11.02 in.] wide, and 0.15 m [5.90 in.] thick. We may mention however that the metal sleepers used at joints in Belgium and Switzerland are double sleepers.

II. DESCRIPTIVE STUDY OF THE PRINCIPAL TYPES OF JOINTS.

a) *General arrangement of the joints and fishplates.*

We will describe in turn the different types of joints reported :

Belgian National Railways.

1° Standard type (Fig. 1).

Flat fishplate of uniform section, lower flange on the outside to prevent the head of the bolt from turning — 4 circular holes —fishplate surfaces not machined and with a cant of 1/3 bearing over their whole length and width on the fishplating surface of the rail.

2° So called C (Cesar) fish plates (1) now being standardised (Fig. 2).

6 hole fishplates, total length 830 mm (2′ 8 5/8″); the fishplating with a cant of 1/3 consists of :

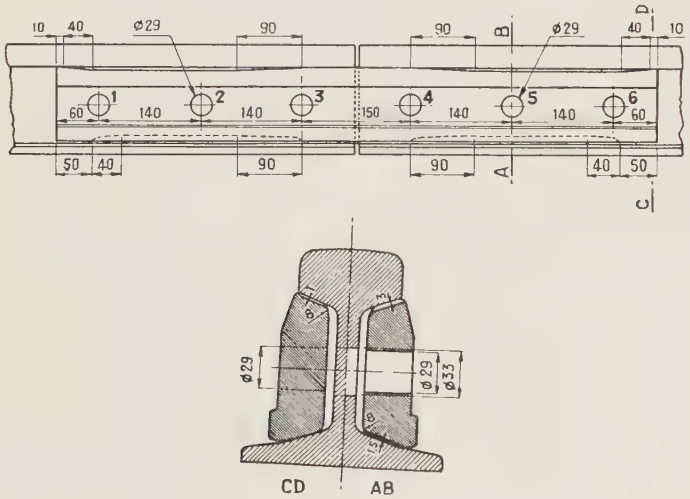


Fig. 2. — Belgian National Railways (S. N. C. B.) « César » fishplate.

a) a middle portion (150 mm = 5.90 in.) which is the true fishplate properly speaking, the upper and lower parts of which are in contact with the corresponding rail surfaces;

b) two elastic arms;

(1) See the work by R. CAMPUS, Honorary Chief Engineer of the Belgian National Railways. The making of a high grade line. The technical economical and social results of 15 years of organisation. (Written in French).

c) two outer portions each consisting of a heel (50 mm = 1.96 in.) resting on the fishplate area of the flange and a stop (10 mm = 0.39 in.) separated from the fishplate area of the head by a play of 1 mm (0.039 in.) when bolts 2 and 5 are not tightened up.

Tightening up these two bolts brings the elastic arms closer to the rail web and forces the heels upwards over the fishplate surfaces of the flange until the stops come in contact with the fishplate surfaces of the rail head.

Danish State Railways (Fig. 3).

Uniform section fishplate — upper and lower flanges on the outside and upper flange on the inside. Four circular holes — fishplate area with a cant of 1/3 bearing over the whole length and width on the fishplating of the rail.

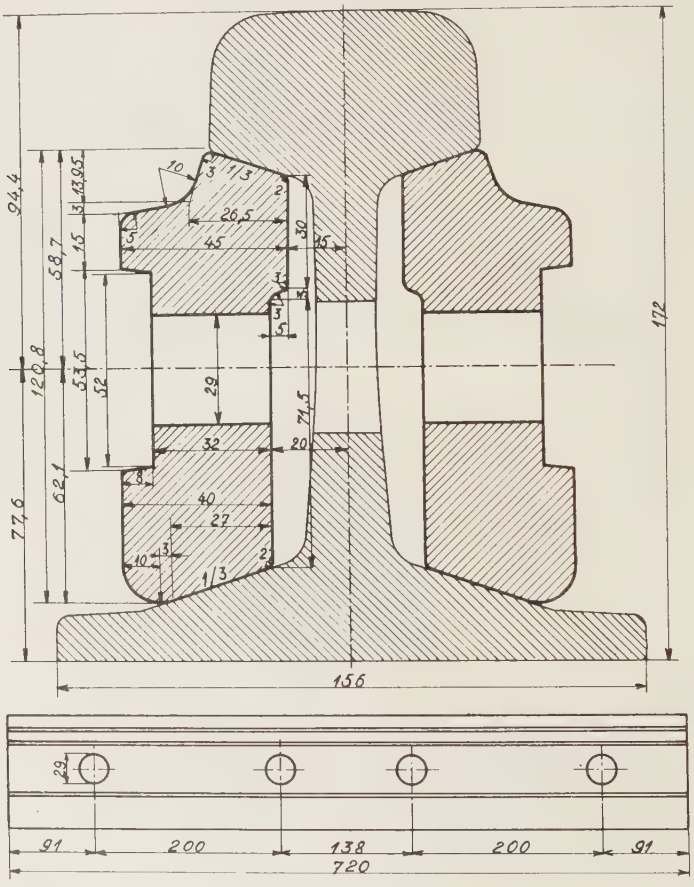


Fig. 3. — Danish Railways fishplate.

French National Railways (Fig. 4).

Angle fishplate with middle flange — bottom flange on the outside — 4 circular holes with the fishplating not machined,

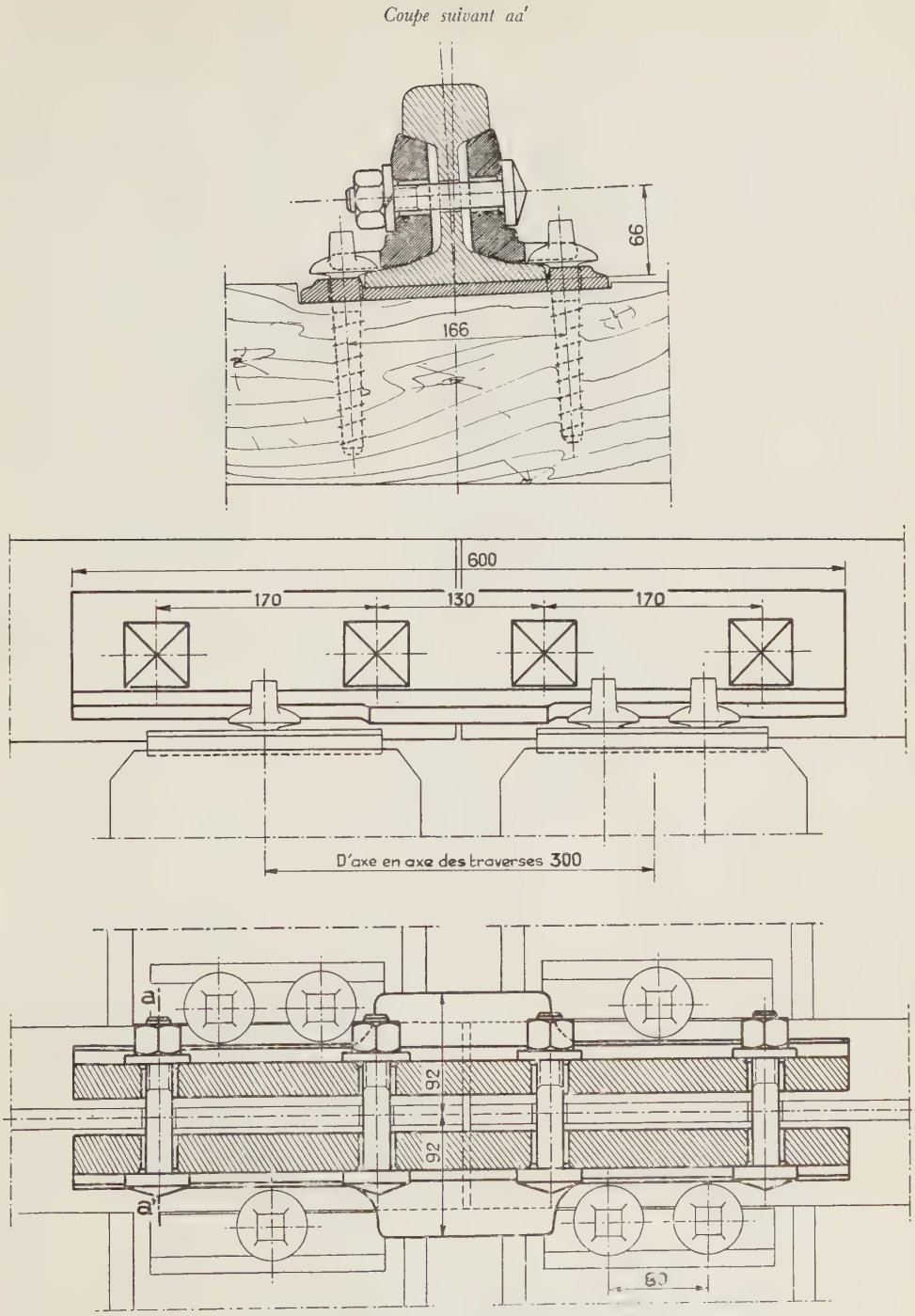


Fig. 4. — French National Railways (S. N. C. F.) fishplate.

D'axe en axe des traverses = from centre to centre of the sleepers. — *Coupe suivant aa'*. = *Section aa'*

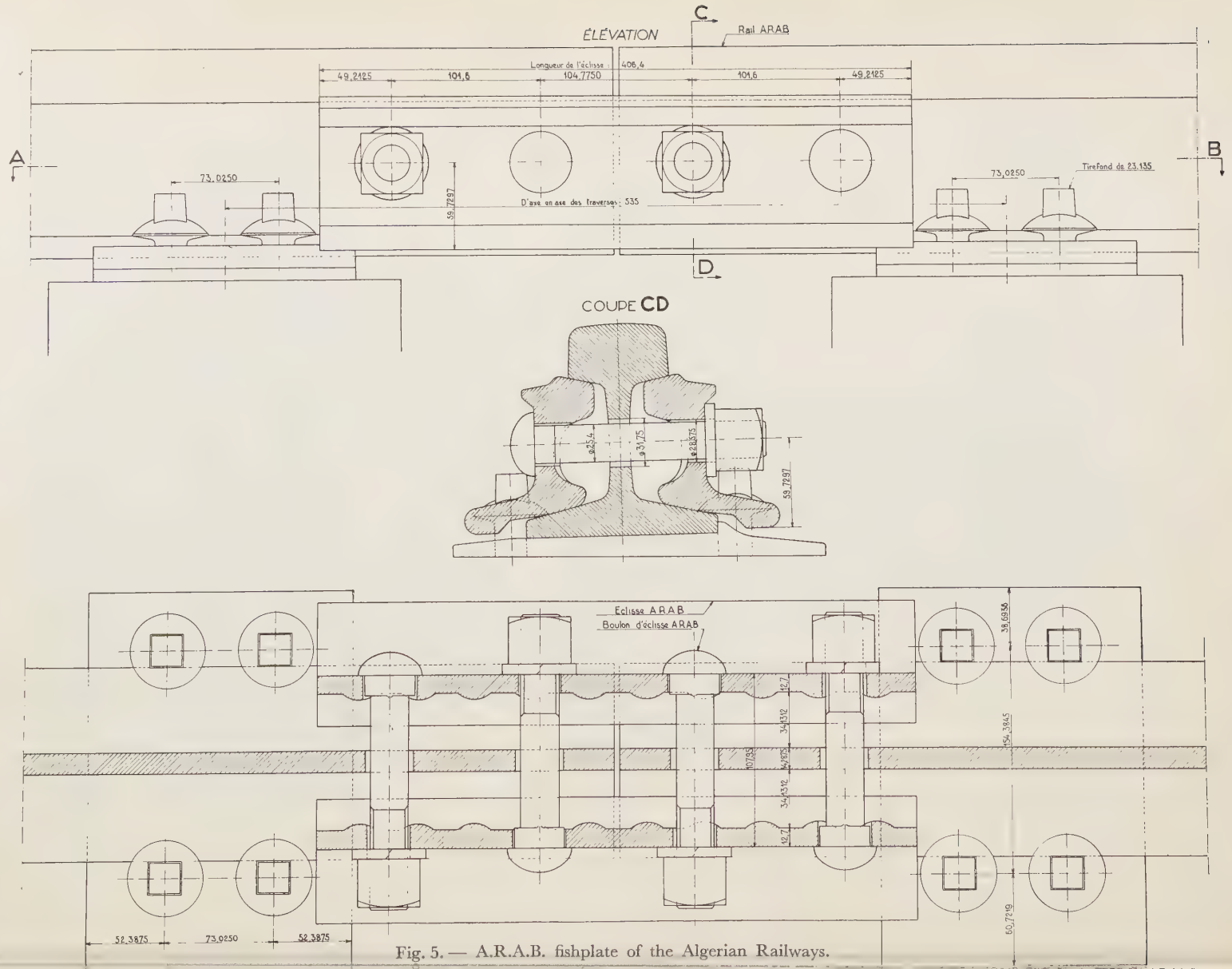


Fig. 5. — A.R.A.B. fishplate of the Algerian Railways.

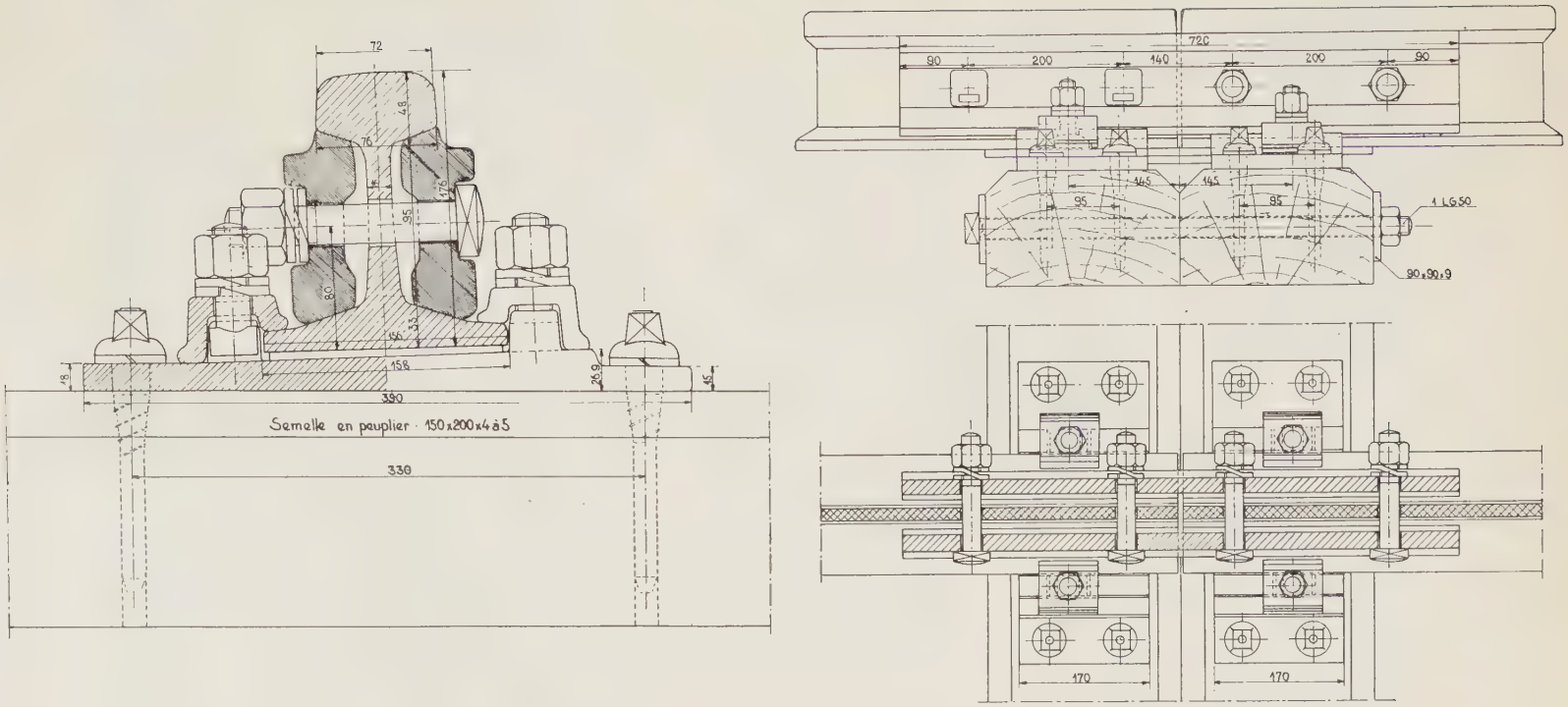


Fig. 6. — Netherlands Railways fishplate.

Semelle en peuplier = Poplar sole plate

bearing over their whole length and width on the fishplating of the rail.

Algerian Railways (Fig. 5).

Cormer angle fishplate with reinforced web having vertical trapezoidal ribbing 4.7 mm (0.164 in.) thick and 12.7 mm (0.499 in.) wide — flanges at the top on the inside and outside — bottom flange on the inside — 2 circular holes (1 and 3) and 2 elliptical holes (2 and 4) — flat upper fishplate surface canted 23/100 bearing on the corresponding rail surface over its whole length and width — lower fishplate cylindrical with a radius of 355.60 m (1 166′ 8″) only bearing on the corresponding rail surface by a generatrix.

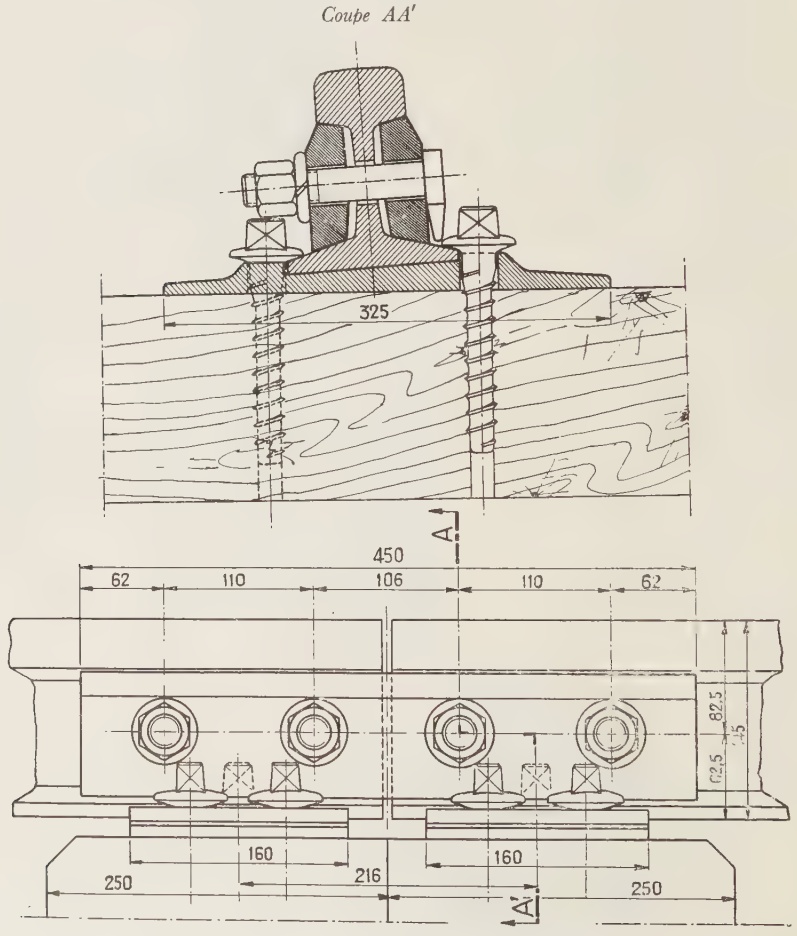


Fig. 7. — Swiss Federal Railways fishplate.

Netherlands Railways (Fig. 6).

Flat fishplate of uniform section — inner and outer flanges both top and bottom — 4 cylindrical holes — fishplate surface not

machined with a cant of 1/3 bearing on the rail fishplating over its whole length and width.

Swiss Federal Railways (Fig. 7).

Flat fishplates of uniform section — 4 circular holes — fishplate surface with a cant of 1/4 bearing over the whole length and width on the rail fishplating.

The table below sums up the principal characteristics of the fishplating as given by the Administrations consulted.

ADMINISTRATIONS	RAILS				FISHPLATES (per pair)				
	Weight	Section	Moment of inertia	Modulus of resistance	Weight	Length	Section	Moment of inertia	Modulus of resistance
	kg/ml	cm^2	cm^4	cm^3	kg	cm	cm^2	cm^4	cm^3
Belgian National Railways:									
ordinary fishplate	50	63	2030	285	—	57	64	498	91
C fishplate	50	63	2030	285	—	83	64	—	—
Danish State Railways . .	60	77	3090	331	45	72	81	957	157
French National Railways .	50	65	2019	248	27	60	—	—	—
Algerian Railways	50	63	1769	231	—	40.6	66	—	—
Netherlands Railways . . .	63	81	3392	350	45	72	81	998	158

On all the railways the ratio between the section of the rail and fishplate is very near unity, and that of the moments of inertia 0.3. As for the ratio between the modulus of resistance, it appears that these increase with the weight of the rail : 0.3 approximately for 50 kg (110 lbs.) rails, 0.45 approximately for 60 and 63 kg (132 and 138.89 lbs.) rails, as does the ratio of the weight : 0.55 for 55 kg rails and 0.75 for 60 and 63 kg rails.

There appears to be no rule as regards the length of the fishplates. The ratio between this length and the distance between centres of the joint sleepers varies from 0.75 (Algeria) to 2 (France, Belgium), 2.3 (Denmark) and 2.9 (Holland).

b) *Arrangement of the rails at joints.*

All the railways consulted only reported joints with 4 hole fishplates as current types, with the exception of the Belgian type C joint which has 6.

The table on page 139/13 gives the dimensions of drilling the rail :

The diameter of the holes in the web of the rail to take the fishplate bolts generally lies between 30 and 35 mm (1.18 to 1.37 in.), i. e. 20 to 25 % of the total height of the rail. In order to reduce the risk of cracks which generally start in the fishplate holes, the French National Railways has adopted a much smaller diameter of hole (23 mm = 0.905 in.), i. e. about 16 % of the total height of the rail. We believe the Belgian National Railways are considering adopting a similar arrangement.

On all the railways the position of the holes depends on that of the rail fastenings on the sleepers in the neighbourhood of the

joint, as it is necessary to be able to tighten up these fastenings without the fishplate bolts getting in the way and vice versa. For this reason, the Netherlands Railways. have increased the distance between centres for the holes in the rail from 115 to 200 mm (4.52 to 7.87 in.) In general (Belgium, France, Switzerland) the axis of the joint sleeper more or less coincides with the centre of the two fishplate holes.

In making the joint, obviously the running surfaces of the adjoining rails will be made to coincide as far as possible. When the joint is made with new rails, small differences in the readings due to manufacturing tolerances are usuallly overlooked. However such differences may be far from negligible. To overcome this difficulty, the Belgian National Railways decided to keep in use only fishplate joints made from one and the same rail cut in two, whether new or being re-used, and to weld all other joints. In this way they obtain the « perfect joint » having fishplates without any play and exact coincidence between the running surfaces. The results have been satisfactory, but it is obviously an expensive plan to carry out. The same solution has been adopted in the case of re-used rails in Holland.

The railways did not give any precise information concerning the tolerances allowed for wear on the running surfaces of two adjoining rails. Only the Belgian Railways (S. N. C. B.) gave this as 1 mm (0.039 in.). It would appear that in practice the other railways make use of the same figure. When this tolerance is exceeded, steel packings are used to make up the difference (the « SHIM » for example) or special fishplates.

The Belgian Railways (S. N. C. B.) report that when the difference in height of the rails varies from 1 to 5 mm (0.039 to 0.196 in.), it is made up either by shims or special joining fishplates according to whichever are available, and when the difference exceeds these figures, connecting rails are used.

The French Railways (S. N. C. F.) only make use of shims in the case of worn rails. When laying new rails, the rails are paired off so that the difference is as slight as possible, and in any case less than 1 mm.

Burrs soon form at the ends of rails in contact; these are only filed or chiselled off when they become a nuisance (on insulated joints for example), and only the Netherlands Railways chamfer the ends of new rails with a file as a preventative measure.

In France and Belgium tests have been made of heat treating the ends of rails to give the metal such physical and mechanical characteristics as will enable it to stand up to the stresses it undergoes. The results obtained in France are too recent for any judgment to be formed.

As for the Belgian Railways we think (cf. the previously quoted work of Mr. CAMPUS) that all new rails laid since 1935 on the main lines have had their ends heat treated; reheating the ends of rails normally cooled to refine the metal and achieve structural equilibrium (annealing) then subjected to compressed air under pressure and for varying lengths of time according to the rail section (running surface, sides of the head, fishplating, web near the holes), or rapid cooling of the ends on leaving the rolling mill.

Certain railways formerly made use of various types of joints in which the rails were supported by special devices in the form of a bridge. These are not used any longer by any railway in recent types of joints (1) and in general the rail rests on the sleepers in the usual way with the same type of fastening : direct fastening without soleplates with coachscrews in Denmark, with sole plates in France, Algeria and Switzerland, indirect fastening by clips and bolts on coachscrewed plates in Belgium and Netherlands.

However the Belgian National Railways have made use of double sole plates at

(1) See below the special case of the insulated joints on the Algerian Railways.

joints, with indirect fastening to the sleeper assemblies. Although good, the results obtained did not seem to justify the extra cost involved. This method was also adopted in Holland in the case of old rails, but has been given up in the most recent cases.

c) *Devices to permit of expansion.*

All the types of joints allow the ends of the rails to expand to some extent. With this object play is provided between the bolt holes, the fishplates and the rails and in the relative position of the various holes. The table below sums up the information received on this subject.

As stated under *b*) above, only the French National Railways drill the rail smaller than the fishplate in order to reduce the fatigue of the rail.

From the information given in the above table, it is possible to determine the total amount of expansion allowed for each type of joint, from the sum of the play between the diameter of the bolts and that of the holes of the fishplate and the rail, the distance between the inside holes of the fishplates and the distance between the holes in the rails at its ends.

This is given by the formula :

$$P = d - 2a + \phi E + \phi R - 2 \phi B$$

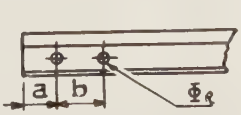
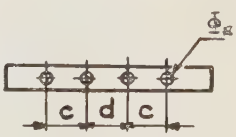
which gives the following results :

Belgian National Railways	18 mm (0.708 in.)
Danish State Railways	24 mm (0.944 in.)
French National Railways	21 mm (0.826 in.)
Algerian Railways	13 mm (0.511 in.)
Netherlands Railways	17 mm (0.669 in.)
Swiss Federal Railways	16 mm (0.629 in.)

This can therefore be increased either by increasing the diameters of the holes in the fishplates and rail, or by decreasing the diameter of the bolt.

d) *Elastic devices.*

Certain types of joints with wooden packings (apart from the insulated joints which

ADMINISTRATIONS	Diameter of the bolts	RAILS			FISHPLATES		
							
	ϕB	a	b	ϕR	c	d	ϕE
Belgian National Railways	25	72	140	33	140	150	29
Danish State Railways	25	64	200	35	200	138	29
French National Railways	20	60	170	23	170	130	28
Algerian Railways	25.4	50.8	101.6	31.75	101.6	104.8	28.6
Netherlands Railways	25	66	200	30	200	140	29
Swiss Federal Railways	25	49.1	110	30	110	106	28

will be dealt with later on) were tried out before the first world war and afterwards used by certain railways on a fairly large scale between the two wars. Joints of this kind were not mentioned by any railways amongst their recent joints.

On the other hand, elastic fishplates have made their appearance in Belgium and France and would appear to have interesting possibilities, at least in the case of track laid with rails of average length.

Thus the C fishplate of the Belgian Rail-

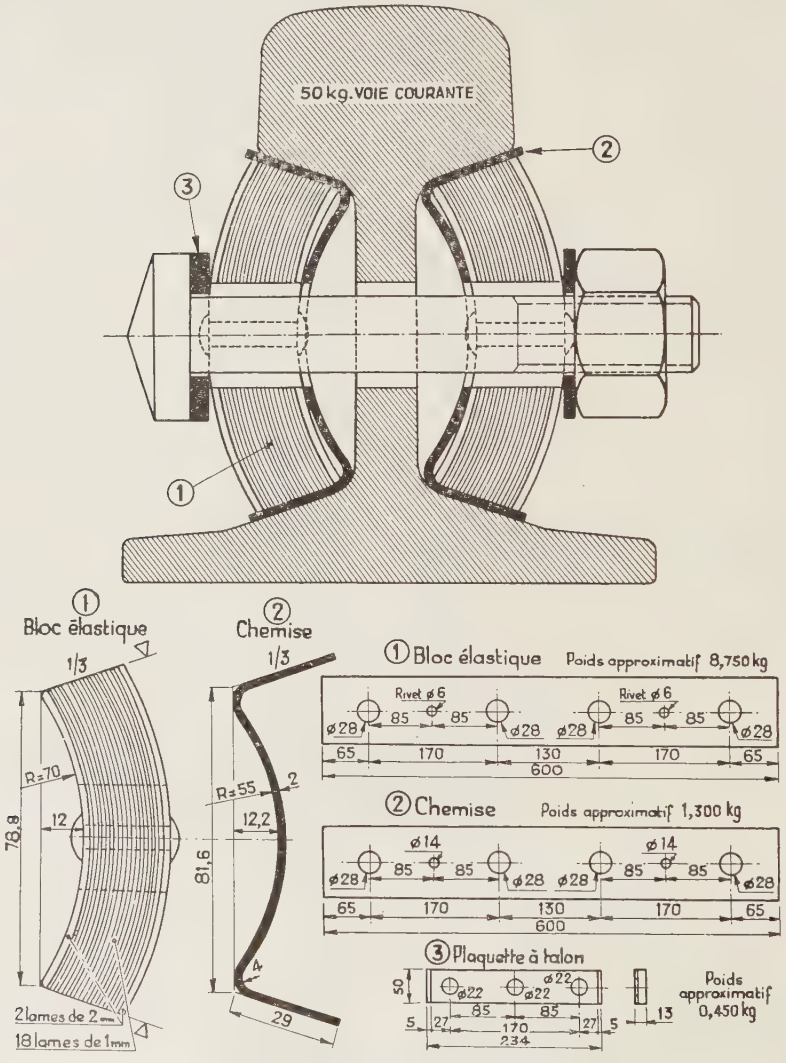


Fig. 8. — Durand joint.

Voie courante = Running line. — Bloc élastique, = Elastic block. — Poids approximatif = Weight approx. — Chemise = Sleeve. — Plaquette à talon = Flanged plate.

ways mentioned above (Fig. 2) is in fact an elastic fishplate.

In practice the elastic arms bend both vertically and horizontally, act as shock absorbers, and oblige the central part to take up any wear as it occurs, thus preventing the joint from sinking and considerably strengthen the ends of the rail by the addition of the tension of the arms to that of the bolts.

These properties considerably prolong the satisfactory behaviour of the joint and make good any possible neglect in maintenance.

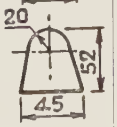
Fishplates of this type in service for more than 10 years on certain sections of the *Brussels-Antwerp* line have given every satisfaction and the Belgian National Railways are now standardising their use.

In France fishplates of a similar kind are now being tried out on the Nord region of the French National Railways : length 910 mm (2′ 11 7/8″) — elastic fishplates with 6 holes — middle bearing 210 mm (8.26 in.) — bearing length of heels and stops 110 mm (4.33 in.) — the elastic arms are in addition arched (3mm [1/8″] deflection). The first trials have given satisfactory results and have now been extended to 20 km (12.42 miles) of track. To enable a comparison to be made some joints have been arranged completely overhanging and others supported by a joint sleeper, with or without a metal sole plate.

Mention must also be made of the tests now being carried out on the French National Railways of the elastic Durand fishplates (Fig. 8), based on a different principle but also giving excellent results. These consist of a bundle of curved blades made of spring steel, assembled by rivets in a steel casing, which takes all the wear. These fishplates, which are as long as and drilled in the same way as the standard fishplates, are fastened by means of 4 bolts bearing down on small flanged plates.

e) *Characteristics and arrangement of the bolts.*

The table below sums up the information supplied by the administrations consulted on this point :

ADMINISTRATIONS	Stem of the bolt				Head of the bolt		Nut	
	Diameter	Length under the head	Length of thread	Thread	Shape	Thickness	Shape	Thickness
Belgian National Rys.	25	145	60	Whitworth 10 threads per inch		12	hexagon.	30
French National Rys.	20	118	55	Standard 2.5		12	hexagon.	24
Algerian Railways . .	25.4	152.4	57.15	Whitworth 8 threads per inch		15.9	square	31.75
Netherlands Railways.	25.5	150	55	»		17	hexagon.	28

When the nut is tightened, the bolt is prevented from turning by the shape of the head one or more sides of which come into contact with the outer flanges of the fishplate. Only the Algerian Railways make use of a different principle : the head of the bolt is round and has a collar (elliptical fustrum of a cone with 34.9 large axis and 28.6 small axis and 143 mm [1.33 × 1.11 × 5.63 in. high] which engages in the elliptical fishplate hole.

Another peculiarity that must be mentioned is the use made by the French National Railways of a nut having the dimensions of the standardised 24 mm (0.94 in.) nut, whereas the bolt is a 20 mm (0.787 in.) bolt. This departure from standard practice has been adopted so that the gangers only have to use a single type of wrench.

Most railways use spring washers of the Grower type to prevent the bolts getting loose; the Belgian National Railways use a two spiral washer which takes a load of 3 t. to flatten out, and the French Railways use so-called reinforced washers of rectangular section, instead of the normal square section.

With the exception of the Algerian Railways which use two nuts on the inside and two nuts on the outside of the track on each fishplate, owing to the arrangement adopted to prevent the bolts turning and the position of the circular and elliptical holes in the fishplate, all the railways put the nuts on the inside of the track. This facilitates checking the track which only has to be gone over in one direction, walking between the rails, to make sure that all the bolts are tight. The Belgian Railways report in addition that this solution has the advantage that if the nut gets unscrewed the bolt remains in place owing to the 1/20th cant of the rail.

f) *Methods of manufacturing fishplates.*

The fishplates are generally rolled hot without any heat treatment (Belgium, France, Netherlands), or sometimes heat treatment is given (ordinary tempering in Belgium). However the Belgian National Railways also use drop-forged fishplates which are always tempered.

In Belgium, ordinary steel is used whatever the manufacturing process (57 kg/mm² $\leqslant$ R $\leqslant$ 65 kg/mm² — R + 2.5 A. $\geqslant$ 102) for rolled fishplates and Siemens, Martin or electric steel containing no more than 0.04 % of S or P for rolled or drop forged fishplates which are heat treated (R = 70 kg/mm² — R + 2.5A $\geqslant$ 110 — E $\geqslant$ 0.65 R).

In France R must lie between 48 and 55 kg and Thomas steel is only admissible if it contains less than 0.03 % of P.

In Netherlands the steel used is mild steel 42 $\leqslant$ R $\leqslant$ 50 kg/mm² — A $\geqslant$ 22 %.

Of the Administrations consulted only the Belgian National Railways, the French National Railways and the Netherlands Railways gave the tolerances allowed in the manufacture of fishplates and detailed the reception tests imposed on their suppliers.

These tolerances are as follows :

a) Length :

± 2 mm (0.078 in.) in Belgium;

— 0 + 5 mm (0.196 in.) in France;

± 3 mm (0.118 in.) in Holland;

b) Section :

± 0.3 mm in Belgium;

+ 0.5 — 0.25 in France;

+ 0.5 — 0 in Holland.

c) angle formed by bearing faces of the fishplate : no tolerances;

d) weight : ± 2 % in France and Holland;

e) drilling : ± 0.5 mm on the diameter and beween centres in Belgium fitted on a template with pins of diameter less by 1 mm than that of the fishplate holes in France;

± 0.5 mm on the diameter in Holland;

± 1 mm between centres lengthwise in Holland;

± 0.5 mm between centres up or down in Holland.

The tests imposed include both macro and micrographical tests (Belgium) and mechanical tests (tensible bending, texture)

in the case of non heat treated fishplates and in addition resilience and Brinell hardness tests in Belgium for heat treated fishplates. These are carried out either on a percentage of the batch of fishplates (1 0/00 in France, 5 0/00 in Holland), or, as in Belgium on a given number of fishplates manufactured from the same ingot (2 per cast in the case of tensile, bending and texture tests for non heat treated rolled fishplates).

III. MAINTENANCE OF THE JOINTS.

a) As a general rule the fishplates are taken apart, greased, checked and repaired if necessary during the usual maintenance operations.

The periodicity varies according to the traffic : it is every 4 years on lines with heavy high speed traffic in Belgium, France, Algeria and Holland.

On certain lines with very heavy traffic, the French National Railways, in addition require the joints to be checked and greased every year, as the rails must always be able to expand freely under all conditions.

b) To make good any wear on the bearing faces of the fishplates, during the general overhaul use is made of restamped fishplates, or shims or similar devices.

c) Worn fishplates are generally restamped either cold or after reheating. Mention must however be made of the special process used on the South-Eastern region of the French National Railways for worn 950 mm (3′ 1 3/8″) 6 hole fishplates used with their S. 52 rails (62 kg/m) (although this type of joint has not been included by the S. N. C. F. among their up to date joints). A slight transversal bend (about 5 mm at the ends) is given to the fishplates under a press in a die made with a slightly modified rail fishplate recess. The stress exerted exceeds the limit of elasticity so as to obtain a permanent deformation. When the fishplate is laid on the track, the centre portion penetrates into the fishplate recess slightly more than the ends, and is consequently slightly lifted up owing to the 1/3 cant of the fishplate surfaces which also raises the ends of the rails and makes up for any wear in the head. It costs very little to carry out this treatment.

d) The level of the joint is generally checked at the same time as that of the track; the Belgian National Railways however, during the last quarter of each year, carry out an additional shovel packing at the joints, making good any longitudinal subsidence without bothering about any warping; to measure these defects they use a 6 m (19′ 8 1/4″) arc with a steel wire (1). In France, in addition to the general revision of the level by measured shovel packing (every 2 years on lines with heavy traffic) measured shovel packing of the joints is being carried out on an increasing scale, either at the end of the year, or else a few weeks before the general packing, or systematically between two checks.

We made every endeavour to ascertain what interest staggering the joints on the track might have from the maintenance point of view.

The Algerian Railways as stated above, have adopted this arrangement on a fairly considerable scale, and consider that staggering the joints, facilitates levelling the ends of the rails. But the Belgian National Railways hold the contrary opinion.

The Administrations consulted have not drawn our attention particularly to any specially convincing results obtained in the maintenance of the joints by the adoption of such and such a type, with the exception however of the Belgian National Railways who appear to have obtained the following results with their C fishplates:

a) lining — only the C fishplates assure perfect alignment on curves of small radius — the ordinary 4 hole fishplates, especially when restamped, give rise to projections at the joints;

b) level : the C fishplates behave better and the additional shovel packing required at the end of the year is much less in the case of these fishplates than with ordinary fishplates;

(1) Similar equipment has recently been tested on the Nord Region of the S. N. C. F.

c) deformation and wear at the joints : — with the ordinary fishplates the whole joint subsides by 2.5 mm (0.098 in.) the trailing rail falls at the end by 0.7 mm (0.027 in.) — the leading rail wears over a length of 50 mm (1.968 in.) and the wear amounts to 1.2 mm (0.047 in.) — the trailing rail wears over a length of 75 mm (2.95 in.) and this wear is complicated by hammering with a displacement of the

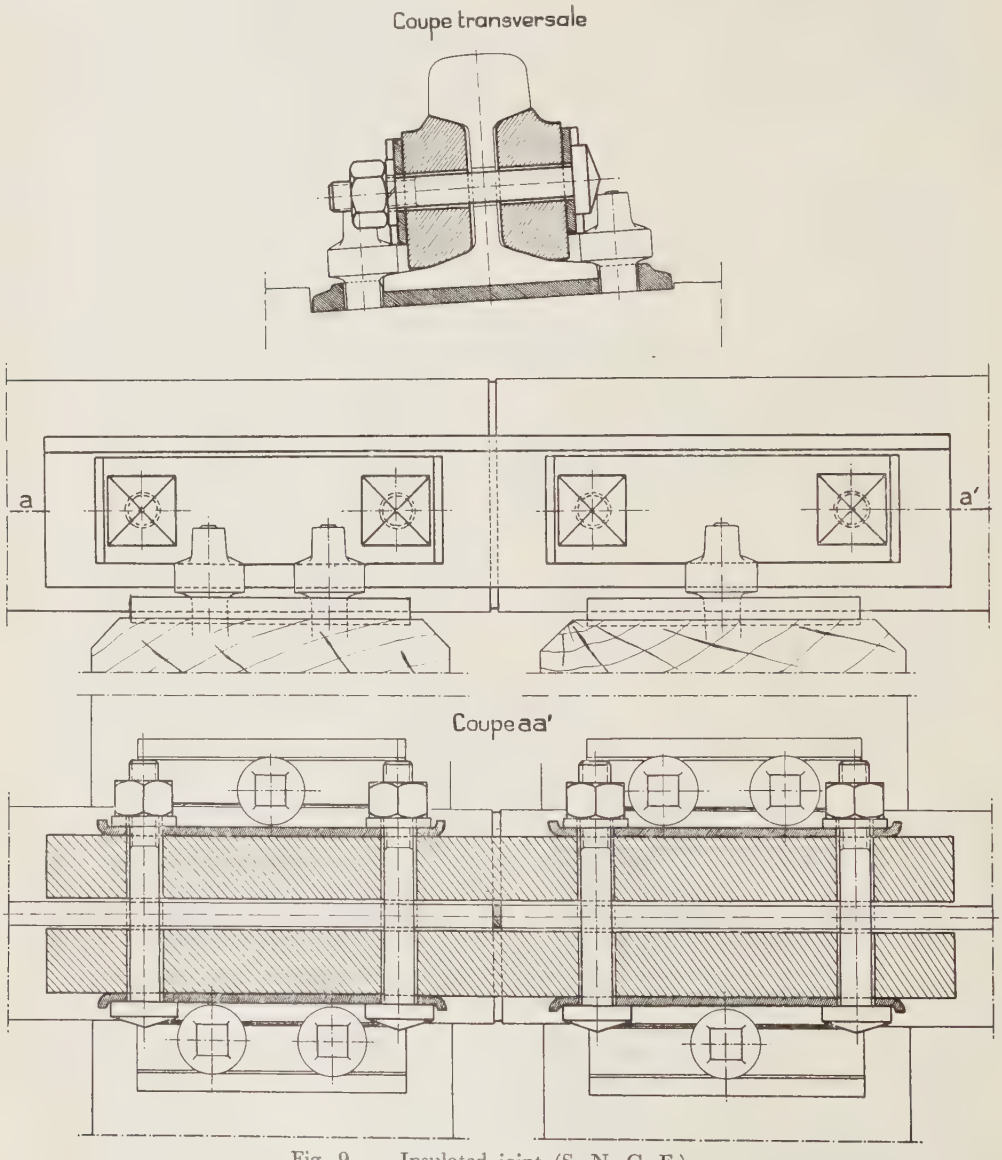


Fig. 9. — Insulated joint (S. N. C. F.).
Coupe transversale = Cross section.

material which makes its measure difficult.

— with C fishplates no deformation of the assembly occurs — the leading rail wears over a length of 30 mm (1.18 in.) and the wear is as much as 0.7 mm; the trailing rail wears over a length of 50 mm, and the wear is as much as 0.5 mm (0.019 in.).

of the breakages, and shims in 4 % of the cases.

IV. INSULATED JOINTS.

These can be divised into two categories : joints with insulating fishplates and joints including insulating bushes.

In the former (Fig. 9) used in Belgium

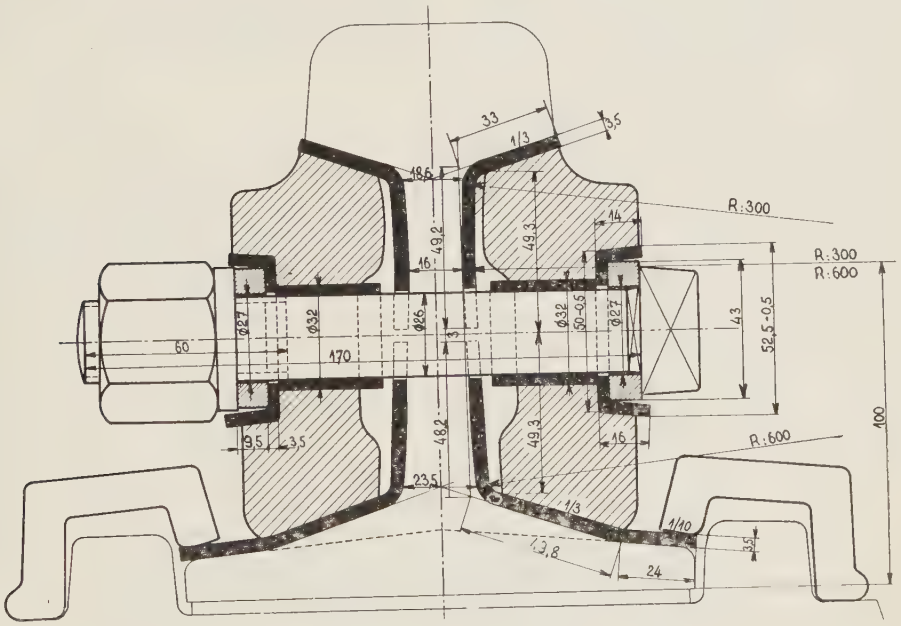


Fig. 10. — Insulated joint of the Netherlands Railways.

From this it would appear that the Cesar joint is a considerable improvement over the ordinary joint, and will play a valuable part, at least in those countries remaining faithful to the classical type of track with rails of average length.

We have not been able to collect any definite statistics about joint breakages.

Only the French National Railways supplied some interesting data in this connection : out of 2 136 broken rails in 1948, 1 171 occurred in the fishplating, i. e. 54 % and nearly 10 % of these breakages in the fishplating of insulated joints. Re-stamped fishplates were concerned in 41 %

and France, the ordinary fishplate is replaced by a flat fishplate made of plywood similar to the fishplate used with ordinary joints; the head of the bolt and its nut provide for tightening up through small flanged steel plates. A packing of some insulating material is placed between the ends of the rails and in the inside of the holes in the rail, a washer with an insulated ring to prevent the current passing from one rail to the other, either directly or through the rail-bolt-plate circuit.

In the second type (Fig. 10) used in Holland, the ordinary fishplate bears on the rail through a packing of some insulating

material, and leakage of the current through the bolts is prevented by insulating washers and rings.

The fishplate is exactly like an ordinary fishplate except that the diameter of the fishplate holes is greater (32 mm = 1.259 in.).

The Algerian Railways make use of the Weber bridge joint (Fig. 11) in the case of A. R. A. B. material, consisting of a metal plate bearing on the two joint sleepers, two flat wooden fishplates, a packing piece and

Apart from certain trials of special joints, which the railways concerned have not even mentioned, the only new solution we have to report is the C fishplate of the Belgian Railways and the trials being carried out in the Nord Region of the S. N. C. F.; the conception of these two types of joints recall the « chevron » fishplate, and may be considered as an interesting improvement thereof.

The main fact to be drawn from this

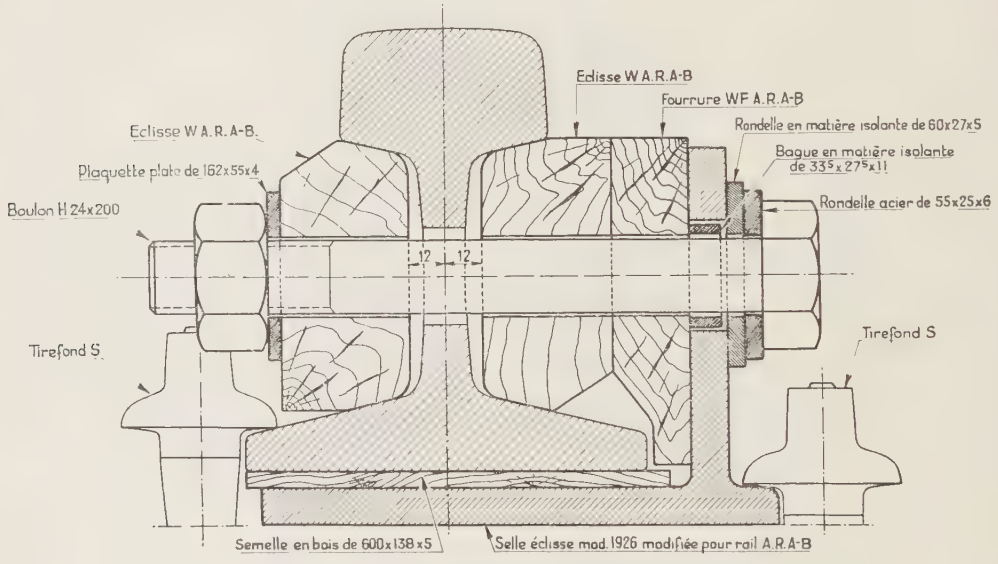


Fig. 11. — Insulated joint of the Algerian Railways.

Eclisse = Fishplate. — Plaquette plate = Flat plate. — Boulon = bolt. — Tirefond = Coachscrew. — Semelle en bois = Wooden sole plate. — Fourrure = Packing piece. — Rondelle en matière isolante = Washer of insulating material. — Bague en matière isolante = Ferrule of insulating material. — Rondelle acier = Steel washer.

sole plate also made of wood, rings and washers of insulating material, the whole assembled by 4 bolts. This joint is very complicated, and difficult to maintain, and the French Railways, which used it before the war on a fairly large scale have now given it up.

CONCLUSIONS.

To sum up, the data collected have not brought out any specially novel solutions.

first part is the simplicity of up to date fishplating which has been reduced to two fishplates assembled by 4 bolts. There have been many trials of complicated fishplating, but maintenance difficulties as regards keeping these complicated assemblies tight enough have always led to their use being given up. In practice there has always been a return to the flat fishplate, generally with ribs, to enable the heads of the bolts to grip on the one hand, and on the other to increase the moments of inertia and the

modulus of resistance. The French standard fishplate alone includes a bottom web, reduced it is true to the central portion; originally this fishplate was a true angle fishplate, but it was found that this led to the warping of the coachscrews. The angle A. R. A. B. fishplate of the Algerian Railways which is very short and situated entirely inside the fastenings of the joint sleepers, escapes this criticism, and it might be interesting to examine the joints fitted with it at a later date.

***

PART TWO.

The use of long welded rails.

In this second part, we have examined rails longer than those rolled directly in the mills and we have considered :

a) the use of rails longer than 30 m (98′ 5 1/8″) as standard practice;

b) trials of very long rails.

a) USE OF 30 TO 60 M (98′ 5 1/8″ TO 196′ 10 1/4″) RAILS AS STANDARD PRACTICE.

Rails obtained by rolling direct.

Before going into the question of these long rails we thought it interesting to give details of the maximum lengths of rails obtained directly by rolling as now laid currently on the permanent way.

The following table sums up the information collected.

With the exception of the Belgian and Swiss Railways which roll 27 and 36 m (88′ 7″ and 118′ 1 1/4″) long rails respectively, the railways normally use 12 to 18 m (39′ 4 1/2″ to 59′ 5/8″) rails. Siderurgical progress has made it possible to roll longer rails, but it is difficult to transport and handle such long rails. Furthermore their use gives rise to the problem of the joint gap. Certain countries, like France, where there are very strict regulations on this subject, have even given up using 24 m (78′ 9″) long rails after using them on a large scale, and gone back to the 18 m rail.

We will see in the third part of this report that the regulations concerning the joint gap differ widely from country to country, and have enabled certain railways, such as the Belgian and Swiss Federal Railways, to adopt 24, 27 and even 36 m (78′ 9″, 88′ 7″ and even 118′ 1 1/4″) long rails.

ADMINISTRATIONS	Normal lengths by direct rolling	Rail section	Weight per lineal metre
Belgian National Railways	27 m	Vignole	50 kg
Danish State Railways	15 m	Vignole	60 kg
French National Railways	18 m	Vignole	50 kg
A. O. F. Railways	12 m	Vignole	30 kg
Morocco Railways	18 m	Vignole	46 kg
Franco-Ethopian Djibouti Addis-Ababa Railways	12 m	Vignole	30 kg
Algerian Railways	12 and 18 m	Vignole	46 kg 49 kg A.R.A.B
Netherlands Railways	18 m	Vignole	63 kg
Swiss Federal Railways	12, 15, 18 24 and 36 m	Vignole	46 kg

Welded rails.

In addition certain railways weld the joints to increase the length of the rails laid on the track and decrease the number of joints.

We will not deal with the use of welding to make up rails of more or less standard length from re-usable sections of old rails — such as the welding of two rails from sections of 12 m (39′ 4 1/2″) rails to make up 22 to 24 m (72′ 2 1/8″ to 78′ 9″) long rails.

Here we are dealing with new rails or re-usable rails welded together to form longer rails than those obtained by rolling direct.

1° *On main line sections* run over by fast trains and with heavy axle loadings, the following railways use long welded rails, 30 m (98′ 5 1/8″) long or longer :

— The Belgian National Railways : 50 kg (110 lbs.) Vignole rails 54 m (177′ 2″) long;

— the Danish State Railways : 60 kg (132 lbs.) Vignole rails 60 m (196′ 10 1/4″) long and 45 kg (99 lbs.) Vignole rails 30 m long;

— the Algerian Railways: 46 kg (102 lbs.) and 49 kg (108 lbs.) Vignole rails 36 m long;

— the Netherlands Railways : 63 kg (139 lbs.) Vignole rails 36 m long;

— the Swiss Railways : 46 kg (102 lbs.) Vignole rails 36 m long.

We may also mention the use of 36 m long rails on the Franco-Ethopian Djibouti to Addis-Ababa Railway obtained by welding 12 m long 30 kg (66 lbs.) Vignole rails together, but this is on a line the traffic characteristics of which it is difficult to compare with those of other systems.

2° *On main lines in stations and on sidings*, only the Belgian, Danish, Algerian and French Railways report the use of long rails.

The S. N. C. B. uses 52.50 m (172′ 3″) long rails on sidings, obtained by welding old rails, after recutting the fishplating.

The Danish Railways have welded two sections 165 and 195 m (541′ 4 1/8″ and 639′ 9 1/4″) long, but normally use 59 m (193′ 7″) long 37 kg/m (82 lbs.) Vignole rails (standard rails 23 m = 75′ 5 1/4″) long in shunting stations and 60 m (196′ 10 1/4″) long 45 kg/m (99 lbs.) Vignole rails on main lines in stations (normal rails on the open track 30 m.

In France and Algeria the main lines in stations are treated the same as main lines in the open line, but welded rails are widely used in station sidings, shunting yards, depots and lines running over paved or metalled roads in the docks; such rails are usually recovered rails of various sections which are welded on site by the aluminothermit process. The length of the rails, which depends on their condition and the track in question, reaches 150 to 250 m (492′ 1 1/2″ to 820′ 2 1/2″) in France and 100 m (328′ 1″) in Algeria.

As for the Franco-Ethiopian Djibouti to Addis-Ababa Railway, it is proposed to weld 96 m (314′ 11 5/8″) lengths on such lines from the standard 12 m long 30 kg Vignole rails.

3° *On metal bridges.* — On such bridges where there is no ballast, it is usually the practice to do away with joints by welding the normal lengths of rails together. In this way lengths of 250 m have been made in Belgium, 240 m (787′ 4 3/4″) in Denmark, 150 m in Algeria, and 200 m (656′ 2″) in Holland, with special devices to allow of expansion at the ends.

In France on bridges without ballast which could not be covered by a single length of rail, the rails corresponding to a section of the bridge without a break for expansion are laid end to end and welded. Joints are provided at the ends of sections taking into account the total length of the bridge which can expand; if this is less than 40 m (131′ 2 3/4″) long a certain number of joints are given a larger gap than usual on each side of the bridge (increase of 50 % over the normal joint gap, but maximum gap less than 25 mm [1 in.]; if it is more than 40 m special expansion devices are used.

4° *In tunnels*, the variation of the temperature being much less than in the open, the rails are generally welded from one end to the other except when insulated joints have to be provided.

The lengths of welded rails in tunnels has reached 360 m (1181′ 1″) in Belgium, 1 600 m (5249′ 4″) in Denmark, 6 000 m (19 684′) in France, 2 200 m (7 218′) in Algeria and 3 420 m (11 220′ 6″) in Switzerland.

These very long rails are joined up with the standard rails by means of a few progressively longer rails at each end of the tunnel; their number and lengths depend upon local conditions (direction, altitude, aeration)

Fastenings to the sleepers.

The fastenings used do not differ from those used on the standard rails on main lines :

Belgian National Railways: indirect fastening by sole plate coachscrewed to the sleeper and rail fastened to the sole plate by clips and bolts.

Danish Railways: direct fastenings without sole plates on the sleeper by means of 8 coachscrews per sleeper.

Algerian Railways : direct fastening to the sleeper with a metal flanged sole plate and held down by 6 coachscrews per sleeper.

Netherlands Railways indirect fastening by means of a sole plate coachscrewed to the sleeper and the rail fastened to the plate by clips and bolts.

Swiss Federal Railways : direct fastening to the sleeper with a metal sole plate in between, using 6 coachscrews per sleeper in the case of wood sleepers, and direct fastening by means of clips and bolts in the case of metal sleepers.

Anti-creep devices.

The Danish Railways (60 m long 60 kg rails - direct fastening without sole plates) the Franco-Ethiopian Railway from Djibouti to AddisAbaba (36 m long rails 30 kg. direct fastening on metal sleepers), and the Netherlands Railways (36 m long rails, 63 kg indirect fastening) do not make use of such devices. On the other hand the Algerian Railways use 18 and the Swiss Federal Railways 9 to 18, according to the gradient, on their 36 m long rails. As for the Belgian Railways, they use the same anti-creep devices with their welded 54 m rails, as with their 27 m rails : 1 side bar per rail bearing on a sleeper which is linked up with the 5 sleepers above it by a batten. If need be — which is very rare — this is reinforced by separate stops.

The Algerian Railways use steel springs as anti-creep devices with their A. R. A. B. rails, of rectangular section 36 mm × 24 mm (1.41 × 0.94 in.) of U form, the branches of which grip the foot of the rail while the rounded part rests on the adjoining sleeper. These are the standard anti-creep devices of the S. N. C. F., but whereas they use two per 18 m rail, the Algerian Railways use 6 on each of the three 12 m rails of which the welded 36 m rails consist, starting from the middle of the rail in each direction, on every second sleeper and arranged head to tail in each case to prevent creep in both directions.

As for the Swiss Railways, they use various types of anti-creep devices : Sinkovitch (U iron laid hot), Milles, Fair or Mathée, placed on every other sleeper from the middle of the rail on one side or both sides of the sleeper according to local and operating conditions; in the case of 36 m rails, the number varies from 9 (on the level and gradients $\leqslant$ 5 $^0/_{00}$) to 14 (gradients between 6 and 10 $^0/_{00}$) and 18 (gradients of more than 10 $^0/_{00}$).

Sleepering.

With the exception of the Franco-Ethiopian Djibouti to Addis-Ababa Railways, where two different rates of sleepering are used : 1 250 and 1 500 sleepers per kilometre, all the railways using welded rails on the open track lay about 1 700 sleepers per kilometre : 1 666 in Belgium, Holland and Switzerland; 1 650 in Denmark, 1 515 in Algeria. The number of sleepers depends on the importance of the lines, not on the length of the rails.

On all the railways, the sleepers are laid closer together near the joints; the distance

from the end of the rail to the axis of the joint sleeper and from centre to centre of adjoining sleepers are :

Belgian National Railways : 142-500-560.5-607;

Danish State Railways : 155-550-581 611;

Franco-Ethiopian Djibouti to Addis-Ababa Railways :

272.5-660-670 (with 1 500 sleepers per km);

272.5-735-810 (with 1 250 sleepers per km);

Algerian Railways : 267.5-630-670;

Netherlands Railways : 125-593-610;

Swiss Federal Railways : 108-542-575-610.

As regards welded joints, only the Algerian Railways use the same arrangement of sleepers on each side of such joints as with fishplate joints; all the other railways consider there is no need for any special arrangement and the sleepering at such joints is identical with the arrangement in the middle of the rails.

Kinds of ballast.

On main lines, all the railways use high grade ballast, hard broken stone with a screen of 40/60 as a general rule, the same as is used moreover on lines of the same category where there are no welded rails.

As for service sidings, all the usual kinds of ballast are used : broken stone, gravel, sand, slag.

Arrangements adopted at the ends of rails and anchoring the track to the bed.

On the running lines (main lines and service sidings) and at the ends of tunnels, the fishplates used with welded rails 36 to 54 m long are identical to those used rails with of the standard length already described in part one of this report. The track is not anchored to the bed in any special way, apart from the anti-creep devices mentionned above.

In the case of longer rails in use on metal bridges, on the other hand, special devices are nearly always used to enable the expansion of the long rails to be absorbed, at least to some extent. The problem is a different one in this case, as in fact it is a question of absorbing not the expansion of the track but that of the bridge. Consequently we will not describe the equipment used for this purpose.

Temperatures and regulations adopted for laying the track.

The Administrations consulted did not all reply sufficiently precisely to the question concerning the temperature at which rails are laid. It would appear however that it is not a matter of indifference at what temperature rails are laid, when it is a question of longer than standard rails, with which the regulations concerning the joint gap do not permit of free expansion.

Certain railways merely recalled these regulations which indeed are the subject of the third part of this report; it can be deducted from this that they have no special regulations concerning the temperature : Belgium, Denmark, Holland.

Other railways however gave precise details on this point : the Algerian Railways in principle lay their 36 m long rails at 15° C (59° F) and the joint is calculated for 18 m.

The Franco-Ethiopian Railway lays rails at a temperature between 35 and 45° C (95° and 113° F).

We way mention in addition that the Belgian National Railways which allow their 54 m rails to be laid at any temperature between 6° and 34° C (42° and 93° F) allow a greater amount of play when the rails are laid than they theoretically should have during operation) 18 mm [45/64″] at 6° when laid and —9° during operation, 10 mm [3/8″] at 18° and 10°, 7 mm [9/32″] at 22° and 18° under the same conditions).

Stresses allowed in long rails.

It appeared to us to be of interest to endeavour to ascertain the experimental studies made in order to determine in the case of very long rails the stresses in the rail, the strength of the fastenings and resistance to displacement of the sleepers on the ballast.

The Algerian Railways merely reported that tests are being carried out, but did not give any description of them.

The Netherlands Railways admit that the stresses are of the order of 35 to 40 tons per rail (63 kg) section 81 cm² (12.55 sq. inch.) — indirect fastening by clips — 36 m rails, i. e. 430 to 490 kg/cm² (6 116 lbs. to 6 969 lbs. per sq. inch.).

The Franco-Ethiopian Djibouti to Addis Ababa Railway is going to lay 48 m (157′ 5 3/4″) long rails directly fastened to the wood sleepers with the same gaps as in the case of 36 m rails, which, according to them in the case of 30 kg rails of 38 cm² (5.89 sq. inch.) section will result in stresses of the order of 400 to 500 kg/cm² (5 689 to 7 111 lbs per sq. inch.).

The Danish State Railways in the case of their 60 m long 60 kg, 77 cm² (11.93 sq. inch.) section rails fastened directly to wood sleepers, have calculated the traction resistance as 850 kg/cm² (12 089 lbs per sq. inch.) and the compression as 1 050 kg/cm² (14 934 lbs per sq. inch.).

The Belgian Railways state that the question is still being studied, without giving any further information. But we might recall that a study of the question has already been published in Mr. C. Lemaire's report to the Paris Congress in 1937 (Cf. February 1937 *Bulletin of the International Railway Congress Association)*.

In view of its interest, we think we should sum it up below as follows :

a) the stress per mm² of section of a rail whose expansion or contraction is completely prevented, is about 0.250 kg per degree centigrade, which results moreover from the application of Hooke's law;

b) resistance to sliding over the ballast of a track laid on wood sleepers, ballasted to the lower edge of the sleepers, is about 570 kg/m (383 lbs per ft.), i. e. 285 kg per line of rails and per metre (191.5 lbs per ft.). This result is very close to that given further on by the Swiss Federal Railways for a track laid on metal sleepers and that calculated in Italy (300 kg);

c) resistance to slip between the rails and sleepers in the case of fastenings by clips (2 000 kg approx. per fastening, i. e. with the sleepering adopted : $\frac{2\,000 \times 90}{54}$: 3 300 kg/m), is appreciably higher than that of the whole of the superstructure on the ballast. It is consequently the superstructure that is displaced longitudinally.

The Swiss Federal Railways have recently carried out some very important studies on this question covering track laid on metal sleepers — with rails of different lengths, in particular a rail 157.5 m (516′ 8 11/16″) long consisting of two sections of 97.5 m and 60 m (319′ 10 11/16 and 196′ 10″) with rigid fishplating.

Apart from data relative to the expansion and opening of the joint gap with which we will deal in the third part, they endeavoured to determine by actual experiment the law of variation of tension in rails submitted to variations in temperature.

Since they were able to determine that the resistance set up by the fishplating to normal expansion is of the order of 20 t and the resistance set up by the ballast to slip of the superstructure is about 260 kg/m (174.71 lbs per ft.) per line of rail (the report did not give precise details concerning the characteristics of the fishplating nor the kind of ballast).

They then endeavoured to determine analytically the supplementary tension which occurs in the rail after the joint gap is eliminated, i. e. after the temperature has risen sufficiently to overcome the resistance of the fishplating and the ballast (1).

(1) This supplementary tension is given by the formula :

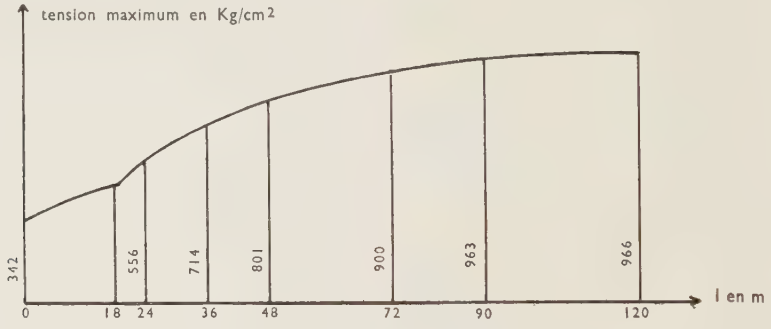
$$\alpha E T s - \left(\frac{P}{S} + \frac{pl}{4S} + \frac{\lambda o E}{l} \right)$$

in which :

α = coefficient of expansion;
E = modulus of elasticity;
S = rail section;
l = rail length;
λo = initial joint gap;
Ts = difference between the maximum temperature of the rail and the temperature at which it is laid;
P = resistance of the fishplating;
p = resistance to friction of the superstructure on the ballast per cm and per line of rail.

Finally they established a formula giving the maximum tension (1), which is equal to the tension developing in a rail before the joint gap is taken up increased by the supplementary tension calculated above.

By means of these formulae, they calculated that in the case of a track where the resistance of the fishplating is 20 t and the resistance to slip over the ballast 260 kg per metre of rail — with a laying temperature of 20° and a joint gap at this temperature of 5 mm and a maximum temperature of 60° — the maximum tension developed in the rail is given by the following curve :



Tension maximum en Kg/cm² — maximum tension in Kg/cm².

This fact is interesting as it brings out very clearly the fact that after the rail is given a certain length, the maximum tension in the rail increases very little.

However the practical tests proposed by the Swiss Federal Railways to support this theoretical determination have not yet been carried out.

General facts emerging from the use of 36 *to* 60 *m long rails.*

Most of the railways report no abnormal creep; the Danish and Swiss Railways have noticed that there is less creep than was expected from the theoretical calculations. As for the Algerian Railways, they have found that considerable creep occurs on lines laid on wood sleepers.

The Algerian Railways also report that certain slight transversal deformations have occurred on lines laid on wood sleepers; the other railways have not reported any deformation, neither vertical nor transversal.

b) TRIALS OF VERY LONG RAILS.

(on main tracks of running lines).

All the above remarks relate to rails 30 to 60 m long. As for using rails considerably longer than this, only the French National Railways report having done so.

They have in fact carried out certain trials of rails of approximately 300 m (984, 3''), after very thorough investigations on the behaviour of soil and permanent way under compression, carried out by Mr. R. LEVI, head of the Technical Services of the Stationary Plant of this railway.

A brief description of these trials is as follows;

A — On a line with very heavy goods traffic (Grande Ceinture near Poissy) a trial length of 400 m (1 312' 4'') without any joint using 46 kg rails was laid in 1948. The rails are fastened by means of grooved rubber plates on heavy reinforced concrete longitudinals, of the LAVAL type, fastened by means of elastic clips. Connection with the lines at each end is assured by means of the two blade type of expansion joint.

B — On a line with very heavy goods traffic (Longueau-Estrées-Saint-Denis) two

(1) This formula is as follows :

$$\frac{pl}{4S} + \alpha ETs - \frac{\lambda o E}{l}$$

trial sections each 3 600 m (3 937 yards) long were laid; 46 kg re-used rails were used, welded into 288 m (944′ 10″) lengths, with 1 666 sleepers per km connected together by two blade type expansion joints (Fig. 12). This consists of a blade able to move and a fixed set stock rail, resting on wood sleepers by means of coachscrewed bearing plates to which the stock rail is bolted, the plate assuring that the blade can move longitudinally, but lateral movement being prevented by clips and guide plates. One of the tracks is laid on wood sleepers with direct fastenings, without sole plate, using 6 coachscrews per sleeper. The other track is laid on prestressed concrete sleepers, with elastic fastenings (elastic bearing plate in grooved rubber, elastic spring clips and bolt coachscrews (1)). The two sections were laid at the end of the second quarter of 1949, at temperatures between 25° and 30° C (77° and 86° F); the rails were welded together electrically into 144 m (472′ 5″) lengths in the shop and transported to site on specially designed wagons, two lengths then being welded together on site by the aluminothermit process.

In the above two cases no deformation of the track has been observed even during the great heat of the summer of 1949. The expansion recorded (displacement of the blade in comparison with the stock rail) did not exceed 1 mm (3/64″) per degree and only the ends of the rails (a length of about 50 m = 164′ 1/2″) moved.

It would be of particular interest to follow the results obtained on these two sections, and in particular to compare the track on wood sleepers with direct fastening by coachscrews and the track on reinforced concrete with elastic fastenings under great stress.

C — Again on a line with very heavy goods traffic (Charenton-Maison-Alfort) a trial section of about 2 000 m (6 561′ 8″) with curves of 2 000 m, 1 200 m and 850 m (6 561′ 8″, 3 937′ and 2 788′ 8″) radius was laid with 220 m (721′ 10″) long rails, formed of LP 49 kg — 18 m rails with metal sole plates, fixed by 6 coachscrews to wood sleepers. The joints are made up with blade type expansion joints, some of which are insulated.

D — Finally, on a line with very heavy high speed passenger traffic (Paris-Marseilles) near Berre, a final trial section of 5 300 m (5 796 yards) is now being laid. The rails are 18 m long 62 1/2 kg/m (PLM rail) laid on metal sole plates and fastened by 6 coachscrews per sleeper. They are welded into 250 m (820′ 2 1/2″) lengths and connected by blade type expansion joints, some of them insulated. The ballast will be levelled off to the top of the sleepers.

In these last two cases, the trials are too recent for any conclusions to be drawn.

Conclusions on the normal use of very long rails.

The Administrations now using as standard practice rails longer than 30 m, are very pleased with them and do not intend to reduce the length but rather to increase it.

The Belgian National Railways are going to carry out trials in the near future of rails in lengths of more than 54 m (177′ 2″) and report that the difficulty is not the welding, nor the stresses, but joints which must for one reason or another be retained (insulated joints, in connection to points and crossings accidental breakage, etc...).

The Danish State Railways, are very satisfied with their 60 m (196′ 10 1/4″) long rails and will continue to use such rails.

The Algerian Railways will use 36 m (118′ 1 1/4″) long rails for all future replacements and even 72 m (236′ 2 3/4″) lengths on track laid on reinforced concrete sleepers.

The Franco-Ethiopian Djibouti to Addis-Ababa Railway are now laying 36 m long rails and are considering using 48 m and even 60 m (157′ 5 3/4″ and even 196′ 10 1/4″) lengths.

The Netherlands Railways consider it

(1) See the description of this type of fastening in the report of M. GONON to the LISBON Meeting of the Enlarged Permanent Commission (June 1949) in the March 1949 issue of the *Bulletin of the International Railway Congress Association.*

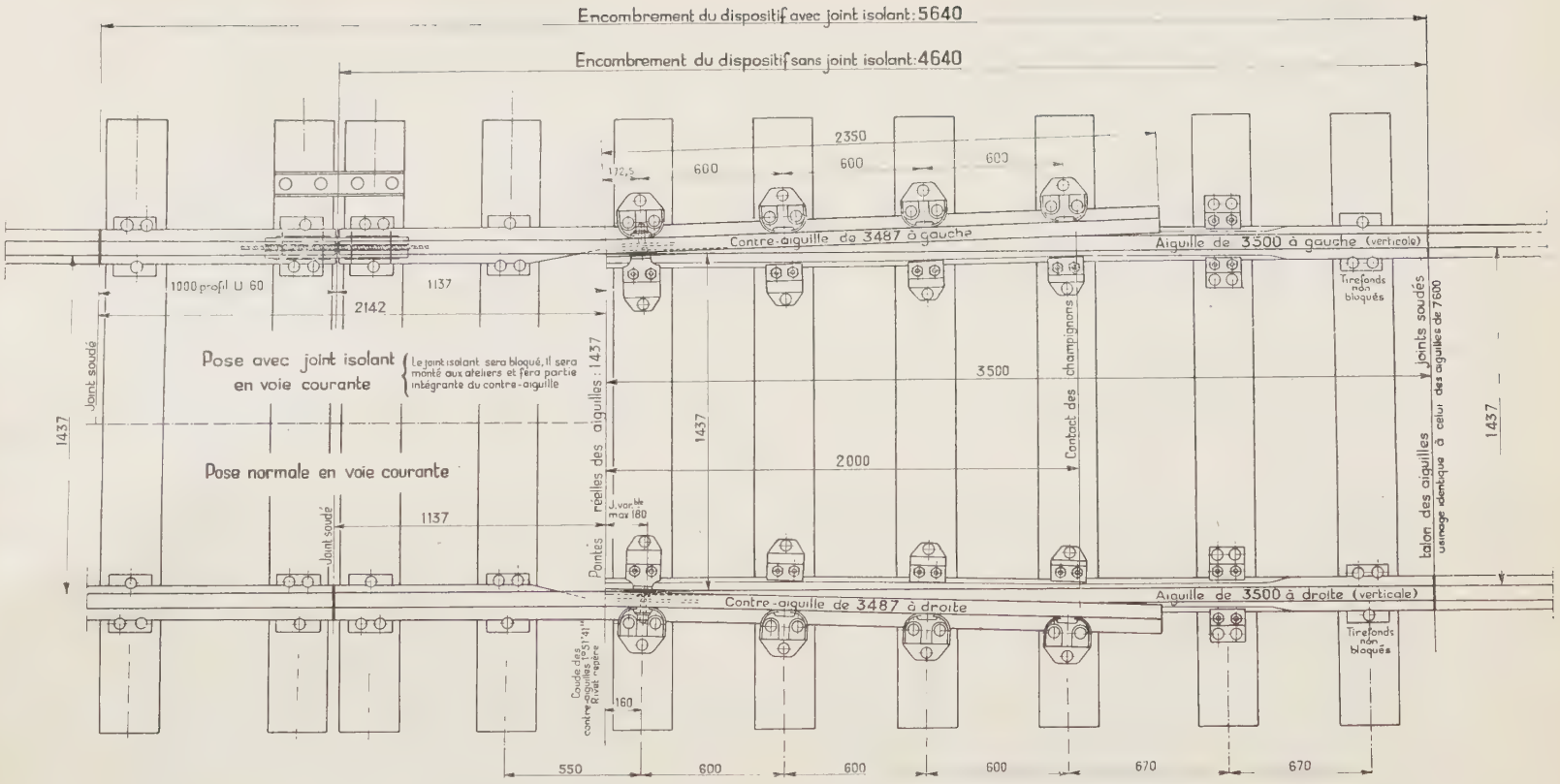


Fig. 12. — Blade type expansion joint for lines laid with long rails.

Encombrement du dispositif avec joint isolant = Space taken up by the device with an insulated joint. — Encombrement du dispositif sans joint isolant = Space taken up by the device without an insulated joint. — Contre-aiguille de 3487 à gauche. = 3487 stock rail on the left. — 1000 profil U 60 = U. 60 section. — Tirefonds non bloqués = Coachscrews not locked. — Pose avec joint isolant en voie courante (Le joint restant sera bloqué, il sera monté aux ateliers et fera partie intégrante du contre-aiguille) = Laid with an insulated joint on the running line. (The insulated joint will be locked; it will be mounted in the shops and form an integral part of the stock rail). — Talon des aiguilles = Heel of the blade. — Joints soudés = Welded joints. — Usinage identique à celui des aiguilles de 7600 = Machining, identical with that of the 7600 blades. — Pose normale en voie courante = As normally laid on the running line. — Contre-aiguille de 3487 à droite = 3487 stock rail on the right. — Aiguille de 3500 à droite (verticale) = 3500 blade on the right (vertical). — Pointes réelles des aiguilles = Real point of the blades. — Coude des contre-aiguilles. Rivet repère. = Notch of the stock rail. Locating rivet.

advisable to stop at 36 m or 48 m at the most, for reasons of economy and facility of laying, and for safety reasons. They state it is necessary to proceed with caution lest any unforseen circumstances arise.

As for the French National Railways, we will see in the third part that up to date they have not been able to consider using lengths exceeding 18 and 24 m (59′ 5/8″ and 78′ 9″) as standard practice owing to the very strict regulations imposed by the public authorities as regards the joint gap (1). In the trials of very long lengths described above which they where authorised to carry out, the expansion apparatus used can in theory absorb the free expansion of the rails. In this way it will be possible to study the real expansion of the track with the different types of superstructure under trial.

The cost of welding and the expansion apparatus for the lengths adopted is very close to the cost of the standard superstructure with 18 m long rails and fishplate joints, but the arrangement adopted will in practice make it possible to reduce very appreciably the maintenance costs for both track and rolling stock. Obviously, it is far too early to make any definite statement, but the first observations on the resistance of the track to the effects of expansion and the improved running obtained are encouraging and very promising.

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THIRD PART.

Regulations governing the joint gap.

I. — THE JOINT GAP IN TERMS OF THE TEMPERATURE.

In the case of rails not more than 24 m long, all the railways consulted continue to make use of joints whose gap corresponds to the formula of free expansion

$$\lambda = \alpha \times l \times \Delta t$$

l being the length of the rail;

α the coefficient of expansion of the steel in the rail, i. e. approximately $0.110 = \overline{10}^4$;

Δt the variation in the temperature of the rail.

For example :

Belgian Railways	12 m rails :	7 mm (0.275 in.) at — 10°; 0 at + 43°;
Weak superstructure	18 m rails :	10 mm (0.393 in.) at — 10°; 0 at + 40°;
Strong superstructure (2)	18 m rails :	9 mm (0.354 in.) at — 10°; 0 at + 35°;
Danish Railways	23 m rails :	12 mm (0.472 in.) at — 5°; 0 at + 20°;
S. N. C. F.	18 m rails	14 mm (0.551 in.) at — 10°; 0 at + 60°;
Netherlands Railways	18 m rails :	9 mm (0.354 in.) at — 10°; 0 at + 30°;
Algerian Railways	18 m rails :	14 mm (0.551 in.) at — 10°; 0 at + 60°;
Morocco Railways	18 m rails :	15 mm (0.590 in.) at — 5°; 0 at + 65°;
Franco-Ethiopian Railway . . .	24 m rails :	10 mm (0.393 in.) at + 20°; 0 at + 59°;
Swiss Federal Railways.	24 m rails :	15 mm (0.590 in.) at — 18°; 0 at + 38°.

On all these railways within the temperature variations given, taken on the rail, the formula is practically the same; in fact if we take the permissible expansion per degree and per metre of length of rail, we get figures very close to the coefficient of expansion quoted above, varying from 0.106 to $0.125 \times \overline{10}^4$.

But the extreme temperature variations vary considerably between the minimum corresponding to the maximum gap allowed and the maximum corresponding to complete closing of the gap; this enables certain railways, by decreasing this variation, to decrease the joint gap, thereby risking setting up stresses when the rail

(1) We have not mentioned some 30 m (98′ 5 1/8″) rails still in use in Alsace Lorraine, corresponding to German track standards.

(2) Rails of 50 kg (110 lbs.) per m and overmore than 1 500 sleepers per km; indirect fastening on Angleur plates.

temperature exceeds that at which the gap will close up. This is the case in particular on the Danish and Netherlands Railways, apart from the Franco-Ethiopian Railway where the climatic conditions are very different from that of Europe.

It will be noted that the maximum joint gap does not exceed 15 mm. The impact effect of the wheels passing over the joint becomes in practice too serious when the joint gap exceeds this amount. Therefore if we wish to maintain this rule of free expansion under wide temperature variations, it is not possible to increase the length of the rails above 20 m (65′ 7 3/8″); and this is why the S. N. C. F. have given up laying 24 m (78′ 9″) rails with joint gaps corresponding to free expansion for a wide temperature variation.

The railways who have laid longer rails than this (see Part II) have only been able to do so by allowing :

— either, as we have already seen in the case of rails shorter than 24 m, the joint gaps to close at a relatively low temperature, thereby allowing a certain stress to develop in the rail, though not serious enough when taken in conjunction with the characteristics of the superstructure to lead to accidents;

— or no free expansion of the rails, which are submitted, even before the joint gap is completely closed, to certain stresses due on the one hand to the resistance of the fishplating to free expansion, and on the other to the friction of the different parts of the superstructure.

In the first case, there is :

The Danish Rrailways :

30 m rails 12 mm (0.472 in.) at 5°; 1 mm (0.039 in.) at + 30°.

Netherlands Railways :

24 m rails : 12 mm at — 12°; 1 mm at + 32°;

30 m rails : 16 mm (0.630 in.) at — 12°; 1 mm at + 32°;

in the case of 36 m rails, the temperature variations are still less : 16 mm at — 6°; 2 mm (0.078 in.) at + 30°.

These figures apply to track laid with indirect fastenings and gravel ballast. When broken stone is used for ballast, the joints are allowed to close up more quickly and the gap is smaller :

24 m rails : 11 mm (0.433 in.) at — 12°; 1 mm at + 26°;

30 m rails : 14 mm (0.551 in.) at — 12°; 1 mm at + 25°;

36 m rails : 16 mm (0.629 in.) at — 11°; 1 mm at + 26°.

Swiss Federal Railways :

36 m rails : 16 mm at — 6°; gap closed at + 32°;

48 m rails : 16 mm at 0°; gap closed at + 29°;

72 m rails : 16 mm at + 7°; gap closed at + 26°.

On all these railways, the allowable unit expansion per degree and per metre of length of the rail are about the same : 0.104 to 0.115 $\times \overline{10}^4$ and close to the coefficient of free expansion of the steel of the rail. But the temperatures at which the joint gap is closed are relatively low, being about 30° and even 25° and 26° for 24 and 36 m long rails on the Netherlands Railways on ballast of broken stone, 20° and 26° respectively for 48 and 72 m long rails on the Swiss Federal Railways.

In the latter case, moreover, it should be noted that in establishing the regulations governing the laying of these rails, it has been agreed that the joint gap should be 5 mm (0.196 in.) whatever the length of the rail at the average rail temperature during the course of the year which is 20°.

In the second case we find :

Danish State Railways :

60 m rails : 13 mm (0.511 in.) at + 6°; 5 mm at + 20°;

Algerian Railways :

36 m rails : 14 mm at — 10°; 0 mm at + 60°;

Belgian Railways :

a) Strong superstructure (50 kg/m rails or

more) more than 1 500 sleepers per km, indirect fastening on Angleur plates.

54 m rails : 18 mm (0.708 in.) at — 10°; 0 mm at + 35°;

35 m rails : 14 mm (0.551 in.) at — 10°; 0 mm at + 35°;

27 m rails : 12 mm (0.472 in.) at — 10°; 0 mm at + 35°.

b) Weak superstructure (other than the above) :

52.5 m rails : 18 mm (0.708 in.) at — 10°; 0 mm at + 35°;

35 m rails : 17 mm (0.669 in.) at — 10°; 0 mm at + 44°;

27 m rails : 13 mm (0.511) in.) at — 10°; 0 mm at + 42°.

(The Belgian National Railways explain that the above figures correspond to the joints as maintained in operation, but in the case of 54 m long rails, different figures are allowed in making the joints from 18 mm maximum at a temperature of + 6° to 1 mm for a temperature of + 34°).

The unit allowable is in every case less than the coefficient of expansion of the rail steel.

In the case of the S. N. C. B.'s 27 and 35 m rails it is respectively 0.090 and 0.088 $\times \overline{10}^4$ in the case of strong superstructures and 0.093 and 0.090 $\times \overline{10}^4$ in the case of weak superstructures.

In the case of the 60 m rails of the Danish Railways, it is 0.083 $\times \overline{10}^4$.

In the case of the S. N. C. B's 54 m rails, it falls to 0.074 $\times \overline{10}^4$ for strong superstructures and 0.076 $\times \overline{10}^4$ for weak superstructures.

In the case of the Algerian Railways it falls to 0.055 $\times \overline{10}^4$ for 36 m rails simply because the same amount of expansion is allowed for in the case of 36 m rails as in the case of 18 m rails (1).

(1) The S. N. C. F. has also allowed 22 m (72′ 2 1/8″) rails to be laid with the same allowance for expansion as with 18 m (59′ 5/8″) rails giving a permissible unit of 0.099 $\times \overline{10}^4$.

It was interesting to try and find out the reasons or calculations made by the railways who take into account stresses in the rail to determine the joint gaps in terms of the temperature.

The Belgian Railways refer to Mr. Lemaire's report to the 1937 Congress mentioned in Part II of the present report.

The Danish Railways gave no details of their calculations, but state that they have not found any essential discrepancies between the results of the calculations and observations carried out on the track in service.

The Netherlands Railways have made use of their experience of 46 kg rails with indirect fastenings with which it was found that the real expansion is less than the theoretical expansion. They merely state that the calculations they made take into account the possibility of allowing for stresses in terms of the characteristics of the track and the kind of ballast.

The Swiss Federal Railways gave us details of the important studies they carried out which we have already mentioned in Part II of this report regarding the stresses developing in long rails.

As regards the joint gap in terms of the temperature, they recorded the following observations on a 120 m (393′ 8 3/8″) section with 45.9 kg (101 lbs.) rails laid on metal sleepers with fastening by clips, one sleeper in four being welded to the rail :

— the expansion is not the same when the temperature increases or decreases; the variations are irregular, and are also influenced by the passing of trains when the temperature is increasing;

— the curve of the expansion in terms of the falling temperatures is not a straight line, but a parabola of the second degree.

The Swiss Federal Railways then endeavoured to find by calculation a law for the expansion of the rails in terms of variations in the temperature starting from an initial state. They arrived at the conclusion that the joint gap at a given temperature is not solely a function of this temperature but also depends on the initial state (initial joint

gap and initial temperature) and that the gap may have the value between two limits.

$$\pm \left(\frac{P}{\alpha ES} + \frac{pl}{4\alpha ES} \right)$$

P = resistance to slip of the fishplates;

E = modulus of elasticity of the rail;

S = section of the rail;

l = length of the rails;

p = resistance to slip of the superstructure on the ballast.

α = coefficient of expansion of the steel of the rail.

These observations agree with those made by other writers.

II. — MEASURING THE TEMPERATURE.

The temperatures in question above are in principle those of the rails measured by means of special thermometers with metal plates which are placed on the foot of the rail and covered with a protective casing to prevent them being affected by outside influences (solar rays and wind). Certain railways use a small length of rail as a testpiece with a hollowed out head containing the thermometer : this is done, for example, on the Danish and Netherlands Railways.

III. — TOLERANCES ALLOWED IN THE SIZE OF THE JOINT GAP AND CORRECTIONS.

It is generally agreed that the joint gap left when laying the rails is not maintained during operation. It has moreover been found, as explained above, that the joint gap is not necessarily the same at rising and falling temperatures. The following regulations have been reported by the railways for correcting and restoring the joints :

The Belgian National Railways « pulls the joints » when the average joint gap, measured in sections of 180 m (590′ 6 3/4″) is more than 1 mm (0.039 in.) less than the standard gap.

In Denmark and Holland, the tolerances are not fixed, but in the latter country, the standard gaps are restored before each summer.

In Morocco, the joint gaps must not close up over more than 50 m (164′ 1/2″) nor must they exceed 30 mm (1.181 in.).

The Franco-Ethiopian Railways requires corrections to be made as soon as the gaps of two successive joints are closed up during the lowest temperature of the day.

As for the French National Railways, a general inspection of the joints is carried out every year, before the 1st May, in order to restore the joint gaps to the standard figure; the measurements are made by means of a triangular calibrated gauge, at an hour when the temperature of the rail does not vary much, in dull or rainy weather for preference. Compared with the theoretical joint, a tolerance of not less than 30 mm and not more than 50 mm (1.968 in.) is allowed for a distance of 500 m (1 640′ 5″). If the total play exceeds the theoretical play, the excess is allowed to remain (merely making local adjustments if the joints are too tight or unduly slack in certain parts) until the following general overhaul, during which certain short rails will be replaced by standard rails, or certain standard rails by longer rails, and the joints equalised by pulling them lengthways. If the total real play is less than the total theoretical play, less than the tolerance allowed, a sufficient number of short rails are immediately inserted, but the rails are not pulled lengthways to equalises the joints until the next general overhaul. In addition to this annual verification and revision, it is laid down that the normal gaps shall be restored (by pulling lengthways or laying short lengths of rail) as soon as it is found that no gaps remain over at least 50 m of rails in one line (all gaps closed from the first to the last joint); until the normal gaps have been restored, the trains are slowed down when passing over the dangerous sections.

The railways have not given any details about the methods they employ to pull out the joints — only the Danish Railways have reported the use of ROBEL type apparatus.

SUMMARY.

The only important fact that emerges from this third part is that all the railways who lay fairly long rails make use of regulations regarding the joint gaps which take into account the possibility that the rails can stand up to a certain amount of stress which on the one hand brakes expansion as much as possible. i. e. as long as the joint gap is not closed up, and on the other hand makes it possible to state that the gap will not close up at a lower temperature than the maximum temperature the rails has to stand up to. Naturally the admissible stress can be the higher as the superstructure is the stronger.

The railways which have practised this have not reported any drawbacks or inconvenience; it can therefore be taken as proved that it is possible to :

— extend up to some 60 m (196′ 10 1/4″) the length of rails connected together by the usual fishplates with satisfactory joints having a maximum gap of 16 to 18 mm (0.629 to 0.708 in.);

— or, in the case of rails 24 m (78′ 9″) long or more, decrease the joint gap, which is always desirable, provided that, in both cases, the superstructure of the track has the right characteristics to enable it to withstand without damage the stresses likely to develop in the rail.

[385 .63]

List of the stations of lines subjected to the International Convention concerning the transport of goods by railways (CIM).

(Note issued by the « Office Central des Transports Internationaux par Chemins de fer », Berne.)

In November 1949, a meeting held in Berne at the « Office Central des Transports internationaux par Chemins de fer » and attended by representatives of various Railway Administrations, studied how should be published the *List of the stations* of lines subjected to the International Convention concerning the transport of goods by railways (CIM), the last edition of which dated from 1932.

The Berne meeting, acting as advisory committee, was of the opinion that the List should give to those concerned, under a simplified form, the requested information on the stations open to international goods traffic and the Administrations subjected to the CIM. This new list, which will be published as soon as possible by the « Office Central », will constitute undoubtedly a precious, even indispensable, aid for the Railways and their clients.

NEW BOOKS AND PUBLICATIONS.

[385 (02]

LEDUC (Octave). Ingénieur des Arts et Manufactures, Ingénieur en Chef chargé de la Reconstruction au Service technique des Installations fixes de la Société Nationale des Chemins de fer Français. — **Cours de Chemin de fer** *(Railway course)*. — One volume 6 1/2 × 9 3/4 in.) of 382 pages, with 424 fig. and a plate : 1949, Paris (V), Editions Eyrolles, 61, boulevard Saint-Germain. (Price : 1 270 French francs.)

An Author's idea of a railway course is based on several facts. First of all, he must consider the instruction of those he is teaching and the general objectives of the school where he is teaching. Without doubt; he must also assign definite limits to each field.

This is particularly so in the case of the railway. Though he may make extensive use of the resources of civil engineering, mechanics or electricity, to mention only the applied sciences, it is always in terms of the special circumstances of the case, with a given objective in view, A rational report will endeavour to stress the special character of the applications, leaving it to others to pursue the investigations and make the necessary calculations for carrying out any work.

Some such ideas, especially as regards the establishment and equipment of a railway, have inspired the author of this book. The principles, the methods, the particular processes, the working of the equipment and its use are described with the conciseness and clarity of a report without any concern with constructional details. Naturally, numerical data and drawings are given as necessary and to illustrate definite railway devices, such as a loading gauge, sections of sleepers, section of a rail, sleeper dimensions, sections of a light railway bridge, etc.

The book can be divided into two parts, although this is not done in the table of contents. The first covers the establishment of a railway and its fixed equipment, whilst the second deals with its operation from the technical point of view. There is no very marked limit to either part, since the two chapters on *signalling* and the *working of the points* in what we have called the first part, might equally well have come under the heading of technical operation.

The construction of a railway is based on a study of the general characteristics of the permanent way and a reasoned selection of the gauge, gradients and curves. It includes the making of the bed, bridges, the whole of the superstructure together with the track equipment, the fixed equipment of stations, the fixed equipment needed in the case of electrification, the laying of the track on the straight and on curves, and the maintenance of the track.

As the book was written in France, it is only natural that in dealing with the general organisation of a railway, the profound modifications caused by the creation of the S. N. C. F. and subsequent thereto should be reported.

In addition to the two chapters mentioned above, technical operation includes the arrangement of the tracks in stations and station approaches, the arrangement of the stations and their subsidiary installations, train movements, and the carrying out of the transport.

Considerable progress has been made in recent decades in the operation of railways, especially on the French railways. We may mention amongst those dealt with by the author the automatic light block, long distance control or centralised control of the points and signals (the centralised

traffic control of America), automatic shunting of wagons, speeded up goods traffic.

The final chapter devoted to the special features of local railways ends with a note of real value on the Paris Metropolitan Railway.

E. M.

[624 .2]

MENDIZABAL FERNANDEZ, (Domingo), Road Engineer. — **Nuevos Estudios sobre el « Impacto »** *(New studies on Impact)*. — Reprinted from the *Revista de Obras Publicas*, January and February 1949 issues. — One brochure (8 11/16 × 10 5/8 in.) of 24 pages and figures.

For various reasons, the readers of the *Revista de Obras Publicas* have been deprived of information concerning studies published abroad regarding vibrations on railway bridges. The author wished to give them some idea of the most recent work on this very important subject.

To give some idea of its interest, he states that in the United States, the American Railway Engineering Association has set up an « Impact Committee ». In England, the Industrial Scientific Research Department has a special Committee investigating the stresses in metal bridges. Amongst well known works, he mentions :

Impact Railway Steel Bridges, by J. B. Hunley;

A mathematical treatise on vibrations in railway bridges, by C. E. Inglis;

Impact on Railway Bridges, by Ch. Lowney.

The theories of Inglis are the subject of the developments given first of all. They introduced a new element into the question : the effect of braking, in other words the damping out, resulting from the resistance of the bridge to vertical displacement. The elasticity is diminished, and the influence of this is shown by the degree of persistance of the oscillations; the latter last a long time in the case of *long* spans, but are quickly over in short bridges. The author explains how Inglis introduces the damping out factor in his equations.

The other elements that come into play are : the permanent load, the static overload, hammer blows (alterations in the load caused by the weight of the wheels), the acceleration of the mass of the brigde and the acceleration of the mass of the locomotive. Starting from the idea of the proportionality of the deflection at the centre to the stresses developed in the consecutive parts of the bridge, the calculations cover the determination of the deflection. By this means the fundamental formula is arrived at, which gives the deflection at the centre in terms of all the factors indicated and makes it possible to determine the required impact coefficient.

Curves are given representing the deflection corresponding to various hypotheses, and in each case, the total deflection at the centre on the one hand and the deflection due solely to the static overload on the other. The differences between the ordinates represents the deformations due to the dymanic effects. By derivation it is possible to get the speeds and accelerations.

These theories have been checked by experiments carried out on test models of girders. The author gives details about the equipment used by the Illinois University Laboratory. A rectangular bar 36.5 × 15.9 mm (1.437 × 0.625 in.) is run over by various loads at a speed based on the ratio of the span. Various arrangements had to be made in order to make the phenomena comparable. Experiments have been made in which the locomotive has been replaced either by a train with 5 axle loads or by a single load.

A series of curves representing the measured and calculated deflections show how well the theory agrees with the results obtained.

The influence of the counterweight of the wheels is brought out. The explanations given touch upon all the instructive points revealed in their examination.

Certain permissible assimilations give rise to an interesting discussion. In particular this is so as regards the use of the « sinusoïde « as the representative curve of the calculated deflections, the representation of locomotives by small size models with one or five pairs of wheels, the determination of the central oscillations by the theory of the forced vibration of a spring with braked speeds, the effects of the running speed on the overloads, and the effects of the angular phase of the counterweights.

Whilst recognising the value of the work done abroad, the author considers that it would be better to carry out trials in Spain more closely approximating to the characteristics of the locomotives and metal bridges found in that country. He then gives the most important of the conclusions to be drawn from the studies and trials reported.

E. M.

[**625** .111 (66)]

GATFORD (H.) B. S. c. (Hons) M. I. C. E. — **Report on Civil Engineering improvements to reduce the operating expenses of the Sierra Leone Government Railway.** — One brochure (8 1/4 × 12 9/16 in.) of 89 pages with numerous plans. — 1948, London, S.W. 1, The Crown Agents for the Colonies, 4, Millbank, Westminster. (Price : £ 1.11.6 d.).

The Railways of the Government of Sierra Leone consist of a main line 227½ miles long from the Port of Freetown, the capital of the Colony, as far as Pendemba in the Protectorate, 20 miles from the frontier of French Guinea. In addition, there is a branch line 64 1/4 miles from Freetown which runs north-east for 82 3/4 miles. The total length of the system is 310 1/4 miles.

Built in very mountainous country, divided up by many deep valleys, the line has the technical characteristics of a pioneer line. For reasons of economy, it was made to follow the natural profile as closely as possible, with limiting gradients of 20 °/₀₀ and a minimum radius of 5 chains for curves. The gauge is 2 ft. 6 inches. The report stresses the fact that this gauge was carefully chosen as being that for which the future development of the traffic would make it possible to cover the various costs the most quickly (operation and financial charges).

However the financial results have not been satisfactory up to the present. Since the first section of the line was opened in December 1898, the Government has had to pay out a total of £ 2 350 000. This explains the mission given to the author of the report. He had to carry out a thorough investigation into the line in order to decide what improvements could be made in order to effect operating economies : modifications of the layout and profile, strengthening of bridges and allied problems.

During the course of the examination, it was found that in the case of the operating costs, the traction costs were unduly high. This was due to various circumstances : an excessive tractive effort being required owing to the poor maintenance of the track, the presence of curves with insufficient superelevation on gradients, small radius curves at the bottom of gradients making it impossible to get a good start up the hills, too steep a gradient on some part of a section making it necessary to reduce the load over the whole section. Breakdowns are frequent. The high price of coal, which comes from Nigeria, also increases the traction costs.

Begun in 1946, the preliminary work and investigations were continued throughout the whole of 1947. Sufficiently detailed surveys of the layout were carried out to enable the local improvements needed to be decided upon, as well as to discover the

more important alterations required such as rectifications of the layout. The compensation of curves has been gone into more thoroughly, the most important direction of traffic (towards the coast) has been taken into account when a different limiting gradient could be adopted. To the report is appended, in addition to a general map of the system, a series of graphical documents, one in particular showing all the difficult points on the line, the others the new profiles and new layouts.

The second part contains a very detailed analysis of all the traction economies expected from these new profiles and in particular from the levelling out of many switchbacks, the rectification of curves and the shortening of distances due to the new layout which involves more radical modifications. A maximum gradient of 16.6 ‰ has been decided upon going up (towards the interior) and 15 ‰ going down (towards the sea). The curves are compensated on the basis of a resistance of 0.05 % per degree, a figure adopted after much discussion. (A curve of 1° has a radius of 5 730 ft. or 86 818 chains).

A general report of the results, both technical and financial, is given in the form of numerical tables accompanied by useful commentaries. These show that the total expenditure involved will be £ 550 000 and the annual saving should amount to £ 82 000. An amortisation period of 20 years for the capital borrowed at 3 % which only comes into account after two years supposes a ratio of 12.9 between capital and annual receipts. If the estimated savings result, it will be possible to amortise the capital in ten years, after which the full benefits of the improvements will be felt.

Amongst the various recommendations made are : to consider the work as a whole to be carried out straight off from the start, to make use of private enterprise to carry out the work, and to entrust the management of the work to a special independent department.

This report is remarkable for its method and the care which has been taken in the correct determination of the different factors concerned. It is also an instructive example of the influence of the technical characteristics of the line and the regular maintenance of the track on the amount of the operating costs.

E. M.

CORRIGENDUM.

List of questions for discussion with the names of the reporters.

15th. SESSION (ROME, 1950).

Bulletin for November 1949.

Page 830 : QUESTION V.

Please add the name of a co-reporter for the following countries :

Great Britain and North Ireland, Dominions, Protectorates and Colonies, America (North and South), China, Burma, Egypt, India, Pakistan, Malay States, Iraq and Iran :

Mr. L. LYNES, Technical Assistant (Carriages and Wagons), Southern Region, British Railways, London.

Page 831 : QUESTION VI.

The list of countries allocated to the Reporters : Messrs. HOFFET and J. TAPIA must be altered as follows :

Mr. HOFFET : *Belgium and Colony, Luxemburg, Norway, Denmark, Netherlands and Colonies, Switzerland, France and Colonies, Poland, Syria, Austria and Sweden.*

Mr. Javier TAPIA : *Italy, Spain, Portugal and Colonies, Rumania, Bulgaria, Turkey, Greece, Czechoslovakia, Jugoslavia, Finland and Hungary.*

Page 833 : QUESTION VIII.

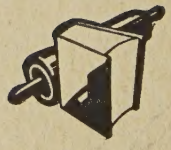
1. Please add the name of the reporter for the following countries :

Great Britain and North Ireland, Dominions, Protectorates and Colonies, America (North and South), China, Burma, Egypt, India, Pakistan, Malay States, Iraq and Iran :

Mr. A. A. HARRISON, Executive Officer (Road Transport), The Railway Executive, British Railways, Marylebone Road, 222, London N. W. 1.

2. The address of Mr. Mario DIAS TRIGO must be as follows :

Mr. Mario DIAS TRIGO, Ingénieur en Chef de la Division d'Exploitation et Statistique à la Direction Générale des Chemins de fer au Ministère des Communications, Rua de S. Mamede (ao Caldas), 21, Lisbonne.



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